POTASSIUM CONTENT OF PUERTO RICAN SOILS AS RELATED TO SUGARCANE GROWING[1]

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INTRODUCTION

Potassium may occur in soils in one or more of the following forms: As a constituent of some primary minerals such as feldspars and micas; associated with a secondary clay mineral as exchangeable potassium; as non-exchangeable potassium, such as within the clay-mineral lattice; and as water-soluble potassium salts.

The primary potassium-bearing minerals that may be found in soils are orthoclase, a potash feldspar, $KAlSi_3O_8$; microline, resembling orthoclase but differing in molecular structure and in optical characteristics; muscovite, a fairly stable mica, $KH_2Al_3Si_3O_{12}$; glauconite, a green granular silicate of potassium and iron closely related to the micas; and biotite, a potassium-magnesium-iron-aluminum silicate, a mica not very resistant to decomposition.

Sericite, or secondary muscovite, a compact or fibrous mica-bearing potassium derived by the conversion or sericitization, of orthoclase feldspar, is also found in some soils.

The potassium in the feldspars and mica minerals is distributed in the coarser sand and silt fractions of the soil.

The range of potassium content varies from about 0.15 percent K_2O in sands to over 4 percent in clays. The clay mineral has the power to fix the potassium cation from the soluble salts in the run-off and drainage waters.

When soluble potash salts are applied to soils, the potassium may be retained in either or both of two forms; namely, the readily available or exchangeable form and the difficultly available or fixed form. The nature of potash fixation have been studied by several investigators and different explanations have been offered. Volk (9)[3] has suggested that K is fixed by muscovite or reacts with silicates to form difficultly soluble muscovite. Truog and Jones (8) have found that alternate wetting and drying hasten the fixation of potassium.

Stewart and Volk (7) said that the variable capacity of different soils to release potassium from the nonexchangeable form for plant consumption

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[3] Numbers in parentheses refer to Literature Cited pp. 193–4.

appeared to be a dominant factor in the nutrition of plants, and that the magnitude of this factor was difficult to measure with chemical soil tests.

Potassium fertilizers are currently used at excess levels in the sugarcane fields of Puerto Rico. There are no potash deposits here and high-priced potash bearing materials are imported. A total of 43,971 tons of potash fertilizer salts[4] at a total cost of $2,863,126 was imported in fiscal year 1951–52. The N-P-K fertilizer formulae sold for sugarcane in Puerto Rico vary from 5 to 20 percent of K_2O and potash is applied at rates varying from 70 to 216 pounds K_2O to the acre. It is estimated that about $600,000 is wasted annually on potash fertilizers applied excessively to sugarcane fields in Puerto Rico.

OBJECTIVE

The objective of this paper is to present data which show that chemical methods are not always reliable when used to determine the potash that plants absorb from the soil.

FINDINGS

Potash-Bearing Minerals of Puerto Rico Soils

Muscovite, a mica primary mineral bearing potassium, was identified (1) in the specific gravity groups: Greater than 2.98, 2.70–2.98, 2.50–2.70, and less than 2.50, of the silt fraction of Catalina clay, a Low Humic Latosol from Puerto Rico. Muscovite was relatively scarce in the first two specific gravity groups, abundant in the third, and present in traces in the last. Small quantities of sericite, a secondary muscovite, were found in the specific gravity group, 2.70–2.98. The primary orthoclase feldspar was absent.

Jeffries, Bonnet, and Abruña (4) reported the absence of micas, especially the common muscovite, in 42 soil profiles, including 118 soil samples of Puerto Rico studied. Traces only of orthoclase were found in the alluvial soils of the Coloso series in the humid area, and in the Juncos and Las Piedras series of the Gray Brown Podzolic group. The principal feldspars identified were those of the plagioclase series: Oligoclase, andesine, and traces of labradorite, all containing sodium and calcium in varying proportions.

Potash Data on Puerto Rico Soils

The data on total potash in Puerto Rico soils are limited to those published in the Soil Survey of Puerto Rico (5) for eight soil profiles including five Latosols and two Gray-Brown Podzolic soils reported in table 1.

[4] 40,795 tons of muriate of potash and 3,176 tons of sulfate of potash at $64.50 and $73.00 per ton, respectively.

Bonnet (2) has reported that the mean available potash extracted by 1-percent citric acid from the surface soils of the soil series of the humid

TABLE 1.—*Total potash in 8 soil profiles of the Puerto Rico humid area*

Soil Group	Soil series	Horizon	Depth	Total K_2O	K_2O per acre
			Inches	*Percent*	*Pounds*
Reddish Brown Lateritic	Catalina	A	0–18	0.08	1,600
		B	18–28	.01	200
		C1	28–68	.91	18,200
		C2	68–88	.84	16,800
		C3	88–125	.75	15,000
Do.	Cialitos	A1	0–6	.06	1,200
		A2	6–12	.15	3,000
		B1	12–24	.20	4,000
		B2	24–36	.16	3,200
		C	36–48	[1]	—
Yellowish Brown Lateritic	Coto	A1	0–7	.18	3,600
		B1	7–17	.15	3,000
		B2	17–40	.23	4,600
		C	40–70	.19	3,800
Do.	Matanzas	A1	0–12	.23	4,600
		B1	12–21	.16	3,200
		B2	21–34	.23	4,600
		C1	34–68	.21	4,200
		C2	68+	.21	4,200
Do.	Nipe	A	0–5	0.9	1,800
		B1	5–15	.02	400
		B2	15–50	[1]	—
		C1	60	[1]	—
		C2	144	[1]	—
Gray Brown Podzolic	Fajardo	A	0–6	.18	3,600
		B1	6–12	.42	8,400
		B2	12–28	.49	9,800
		C	28–50	.60	12,000
Do.	Yunes[2]	A	0–6	.11	2,200
		B	6–9	.17	3,400
		C	9–30	.15	3,000
Do.	do.[3]	A	0–4	.65	13,000
		B	4–14	.42	8,400
		C	14–28	.62	12,400

[1] Trace.
[2] Clay.
[3] Silt loam.

area of Puerto Rico was 0.020 ± 0.0015 percent of K_2O. That of the arid area, with a mean annual rainfall below 55 inches, was 0.023 ± 0.0017 percent of K_2O. There was no significant difference between those mean

TABLE 2.—*Exchangeable potash extracted with 1-percent citric acid from samples in certain soil groups of Puerto Rico*

Sample No.	Soil group	Range of K_2O per acre	Mean K_2O per acre
		Pounds	*Pounds*
6	Ground Water Podzol	100–420	240
31	Reddish Brown Lateritic	80–620	300
10	Yellowish Brown Lateritic	100–1,060	340
24	Gray Brown Podzolic	80–760	340
62	Alluvial	120–1,600	340
18	Lithosols	60–1,300	360
32	Reddish Prairie	120–1,060	400
13	Chernozem	180–760	400
14	Planosol	100–1,140	440
22	Red and Yellow Podzolic	100–1,080	440
14	Rendzina	100–1,200	440
19	Sands	100–1,260	440
10	Reddish Chestnut	120–1,040	460
4	Red Desert	120–980	560
8	Reddish Brown	340–1,060	600
6	Solonchak	280–1,240	660
11	Wiesenboden	120–1,920	680
4	Half-Bog	220–1,620	860

TABLE 3.—*Available potash extracted by sorghum in pot tests from certain Puerto Rico soil groups*

Sample No.	Soil group	Range of K_2O per acre	Mean K_2O per acre
		Pounds	*Pounds*
1	Sands	122	122
2	Planosol	204–344	274
7	Red and Yellow Podzolic	234–598	408
12	Alluvial	158–547–1,572[1]	415
1	Yellowish Brown Lateritic	421	421
7	Reddish Brown Lateritic	276–884	423
2	Bog	360–640	500
7	Reddish Prairie	328–1,017	546
6	Gray Brown Podzolic	314–939	678
1	Half-Bog	684	684
1	Reddish Chestnut	714	714
4	Lithosols	125–2,961	1,019
3	Rendzina	520–1,727	1,050
1	Chernozem	1,496	1,496
1	Reddish Brown	2,054	2,054

[1] San Antón loam in the arid irrigated area.

values. There was a significant positive correlation in the soil series of the humid area between the available potash and the organic matter of those

TABLE 4.—*Mean available potash extracted by sorghum and by 1-percent citric acid from some Puerto Rican soil groups and series in which feldspars were present and clay minerals were identified*

Soil group	Soil series	K_2O per acre extracted by—		Clay mineral
		Sorghum	1-percent citric acid	
		Pounds	*Pounds*	
Gray Brown Podzolic	Ciales	939	280	Kaolin, illite
Do	Humacao	—	420	Kaolin
Do	Juncos[1]	820	200	Montmorillonite, kaolin
Do	Las Piedras[1]	—	120	Kaolin, beidellite
Do	Teja	—	500	Kaolin
Do	Utuado	697	260	Do.
Reddish Brown Lateritic	Alonso	436	380	Do.
Reddish Prairie	Mabí	449, 1,017, 505	400	Kaolin, illite, Beidellite
Do	Paso Seco	542	660	Kaolin, illite
Reddish Chestnut	Fraternidad	—	280	Beidellite (carbonates)
Reddish Brown	Jácana	2,054	420	—
Planosol	Santa Isabel	—	700	Kaolin-illite
Wiesenboden	Guánica	—	220	Beidellite
Alluvial	Aguirre	—	480	Beidellite
Do	Coloso[1]	363, 278, 493	300	Kaolin
Do	San Antón	1,572	380	Illite, kaolin, chlorite, beidellite
Do	Toa	521, 547	420	Kaolin, beidellite
Do	Viví	213, 158	240	Kaolin
Lithosols	Descalabrado	850	200	Illite
Do	Múcara	125, 144, 2,961	360, 840	Beidellite
Do	Pandura	—	220	Kaolin, illite
Mean		747	376	

[1] Soils wherein orthoclase feldspar was identified, together with plagioclase feldspars generally found in the other soils.

surface soils. No such correlation was found for the arid area. The range of values for the 117 soils analyzed is reported in table 2.

Capó (3) reported the contents of available potash, nitrogen, and phosphorus of 56 Puerto Rican soil samples as determined in pot tests using dwarf sorghum, hegari varitey, as a crop index. The available potash data

TABLE 5.—*Mean available potash extracted by sorghum and by 1-percent citric acid from some Puerto Rican soil groups and series from which feldspars were absent and in which clay minerals were identified*

Soil group	Soil series	K_2O per acre extracted by—		Clay mineral
		Sorghum	1-percent citric acid	
		Pounds	*Pounds*	
Red and Yellow Podzolic	Cabo Rojo	234	—	Beidellite, kaolin, montmorillonite
Do.	Lares	408	400	Kaolin
Do.	Los Guineos	570	220	Do.
Do.	Moca	329	480	Kaolin, montmorillonite, illite
Reddish Brown Lateritic	Bayamón	884	120, 300	Kaolin
Do.	Catalina	353, 400	300	Do.
Do.	Cialitos	276	240	Kaolin, traces of illite
Do.	Islote	—	520	Kaolin, illite
Do.	Maleza	—	220	Kaolin
Do.	Matanzas	—	300	Do.
Do.	Río Piedras	296	300	Do.
Yellowish Brown Lateritic	Coto	421	420	Do.
Laterite	Nipe	—	720	Do.
Rendzina	Aguilita	903	380	Beidellite
Do.	Soller	—	600	Kaolin
Planosol	Guayabo	—	280	
Do.	Sabana Seca	204	220	Do.
Ground Water Podzol	Corozo	—	200	Do.
Lithosol	Tanamá	—	720	Kaolin
Mean		440	365	

or *b* values are reported in table 3 as calculated by the Mitscherlich's equation:

$$Y = A\ (1 - R^{x+b})$$

The mean R value[5] calculated for K_2O was 0.036 ± 0.008 with the nutrient concentration expressed in terms of grams per pot.

[5] The mean R values calculated for NH_3 and P_2O_5 were 0.095 ± 0.015, and 0.097 ± 0.021, respectively.

The mean available potash in pounds per acre extracted by the sorghum and by 1-percent citric acid from some Puerto Rico soils in which feldspars were present or absent, is reported in tables 4 and 5, respectively. The clay minerals identified in those soils are also reported.

In soils in which feldspars were present, the mean available potash extracted by the sorghum and by 1-percent citric acid was equivalent to 747 and 376 pounds of K_2O per acre, respectively. The sorghum extracted about twice as much potash. In soils from which feldspars were absent, the mean available potash extracted by the sorghum and by 1-percent citric acid was equivalent to 440 and 365 pounds of K_2O per acre, respectively. The presence or absence of feldspars did not affect the mean potash extracted from the soils by 1-percent citric acid. The potash extracted by the acid was exchangeable potash. The potash extracted generally from the soil by the sorghum, when feldspars were absent, was also exchangeable potash; but when feldspars were present, it was exchangeable potash plus available potash from other sources such as feldspars and micas.

The feldspars identified in those soils were generally of the plagioclase series, except for traces of orthoclase identified in the Coloso, Juncos, and Las Piedras, series (table 4). Since plagioclase feldspars should contain no potassium and since muscovite, another common potash mineral, was generally absent, except in Catalina clay (1) ,the source of the available potash extracted by the sorghum plant is of interest. The plagioclase feldspar minerals might constitute a source of potash since, according to Winchell (10), the albite molecule forms three crystal phases with sanidine, adularia, and microcline, all of which are potash feldspars of the general formula, $K_2O \cdot Al_2O_3 \cdot 6SiO_2$.

Response of Sugarcane in Puerto Rico to Potash Fertilizers and Foliar Analysis

Tests of the response of sugarcane in Puerto Rico to the application of potash fertilizers generally have been limited to a few soils.

Sugarcane varieties B.H. 10 (12), P.O.J. 2878 and M. 275 responded significantly (3) in the field to an application of 400 pounds K_2O per acre. The increase in yields for those varieties were 13, 20, and 19 percent, respectively. No significant yield response was obtained with the M. 28 variety. The amount of potash extracted by the sorghum from the soil sample of Coloso loam taken from that field was equivalent to 364 pounds of K_2O per acre.

The weighted mean reduction in yield from the omission of potassium from the fertilizer in a group of soils in Puerto Rico was reported elsewhere to be 7 percent (6); of which 11 percent was the figure for the humid area. Soils which responded to potash fertilizers, i.e., Coloso silty clay, Vega Alta clay loam, and Mabí clay, all gave optimum yields when supplied with 150 pounds of K_2O per acre. In the irrigated areas in the southern part of the Island there was actually a 3-percent increase in yield when potassium was

TABLE 6.—*Mean yields of cane per acre for 9 consecutive crops*[1] *of P.O.J. 2878 with different potash levels added to acid Vega Alta clay loam*

Crop No.	Crop class	Yield of cane when indicated quantity of K_2O was used per acre per crop		
		90 pounds	180 pounds	270 pounds
		Tons	*Tons*	*Tons*
1	First ratoon	37.7[2]	38.5	38.3
2	Second ratoon	42.3	45.3	45.1
3	Third ratoon	36.1	39.1	37.6
4	Spring cane	49.8	51.2	51.8
5	First ratoon	47.9	50.8	50.0
6[3]	Second ratoon	57.1	61.4	60.9
7[3]	Third ratoon	45.7	50.4	48.9
8[4]	Fourth ratoon	43.2	46.2	45.7
9[4]	Fifth ratoon	40.5	44.8	42.5
Mean for 9 crops[5].		43.2	46.2	45.7

[1] Years 1943–52; a long-time experiment under the Soils Department, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

[2] Each value is the mean of 64 plots including 4 nitrogen levels: 103, 164, 225, 286 lbs. N per acre, and 2 phosphorus levels: 20 and 80 lbs. P_2O_5 per acre; and 8 replications.

[3] Responded to applications of potash in excess of 90 lbs. K_2O per acre. Optimum fertilizer level was 103 lbs. N, 20 lbs. P_2O_5 and between 90 and 180 lbs K_2O per acre, respecively.

[4] Responded to applications of potash and nitrogen in excess of 90 lbs. K_2O and 103 lbs. N per acre, respectively. Optimum fertilizer level was between 103 and 164 lbs. N, 20 lbs. P_2O_5, and between 90 and 180 lbs. K_2O per acre, respectively.

[5] Significant response to potash for the mean of the 9 crops. Least significant difference between means was 1.25 and 1.31 at 1- and 5-percent points, respectively. No response to nitrogen and phosphorus. Optimum fertilizer level for the mean of the 9 crops was 103 lbs. N, 20 labs. P_2O_5, and between 90 and 180 lbs. K_2O per acre, respectively.

omitted. The weighted mean reduction in yields from omission of nitrogen and phosphorus in that group of soils were 30 and 4 percent, respectively.

In a long-time field experiment what were essentially optimum sugarcane yields of P.O.J. 2878 were obtained in the first five consecutive crops, planted in acid Vega Alta clay loam of the humid area of Puerto Rico, with a minimum application of 90 pounds of K_2O per acre per crop per year, as reported in table 6. The sixth and other consecutive sugarcane crops up to the ninth inclusive, and the 9-crop mean yield, responded significantly to the application of potash in excess of 90 pounds K_2O per acre.

No significant response to potash applications in excess of 90 pounds of K_2O per acre was obtained in each of 10 consecutive crops of sugarcane planted under irrigation in Vayas clay, in the arid area of Puerto Rico. The first four crops were of B.H. 10 (2) and the others of P.O.J. 2878.

No significant yield response of M. 336 sugarcane was obtained with applications of 19, 97, 175, and 253, pounds of K_2O per acre, respectively, in sand-lysimeter studies, as reported in table 7. No significant correlation

TABLE 7.—*Mean yields*[1] *of sugarcane and percentage of K in the leaves at various stages of growth when different levels of potash were applied*

Treatment in pounds per acre			Yield of cane per acre[2]	Potassium in leaves when sampled at—			
N	P_2O_5	K_2O		93 days	122 days	152 days	182 days
			Tons	*Percent*	*Percent*	*Percent*	*Percent*
240	175	19	13.32[3]	1.59[3]	1.22	2.69	1.13
240	175	97	18.26	2.37	2.37	2.56	1.78
240	175	175	18.19	2.78	1.98	2.21	1.12
240	175	253	18.51	2.94	2.04	2.34	1.00

[1] M.336 variety harvested at 9.5 months of age in irrigated sand lysimeters; minor elements were added. Unpublished data from experiment under Soils Department, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Least significant differences are 5.56 and 7.70 tons cane per acre at 5- and 1-percent points, respectively.

[3] Each value represents the mean of 4 replications.

was obtained either between the K content of the cane leaves at about 3, 4, 5, and 6 months of age, respectively, and the yields of tons cane per acre or tons sugar per acre obtained with the four different levels of potash applied.

The range of K contents in the sugarcane leaves at a 3-month age varied from 1.59 to 2.94 percent, with the minimum and maximum applications of potash, respectively. Values below 1.80 percent K in 3-month leaf samples of sugarcane tend to indicate deficiency of this element for optimum yields (6) in Puerto Rico.

DISCUSSION

Orthoclase and muscovite, both primary minerals of the feldspar and mica group, respectively, were not generally found in the soils of Puerto Rico studied. The active tropical weathering process has transformed these potash minerals into other combinations difficult to identify. It is thought that the potassium may be attached to the orthoclase feldspars, a group of sodium- and calcium-bearing minerals generally found in these soils.

The soils of Puerto Rico contain total potash in amounts varying from 200 to 18,200 pounds of K_2O per acre, as reported in this paper. The available potash content extracted with 1-percent citric acid varied from 60 to 1,920 pounds of K_2O per acre. The available potash content extracted in pot tests by dwarf sorghum, hegari variety, varied from 122 to 2,961 pounds of K_2O per acre. In soils in which feldspars were present, the mean available potash extracted by the sorghum was about twice that extracted by the 1-percent citric acid and the values were close together in soils from which feldspars were absent.

Chemical methods are therefore not always reliable to determine the potash that plants absorb from the soil

SUMMARY

The potash-bearing minerals, the total potash content in some profiles, the available potash range, and the mean available potash extracted by 1-percent ctiric acid and by dwarf sorghum (hegari) in pot tests, are reported here for Puerto Rican soil groups.

In soils in which feldspars were present, the mean available potash extracted by the sorghum and by citric acid was equivalent to 747 and 376 pounds of K_2O per acre, respectively. The sorghum extracted about twice as much potash.

In soils from which feldspars were absent, the mean available potash extracted by the sorghum and by citric acid was equivalent to 440 and 365 pounds of K_2O per acre, respectively.

Chemical methods are therefore not always reliable to determine the potash that plants absorb from the soil.

Tests of the response of sugarcane in Puerto Rico to the application of potash fertilizers generally have been limited to a few soils.

Optimum sugarcane yields of P.O.J. 2878 were obtained in the first five consecutive crops, in an acid soil of Puerto Rico, with a minimum application of 90 pounds of K_2O per crop per year. The sixth and later sugarcane crops, and the 9-crop mean yield, responded significantly to the application of potash in excess of 90 pounds of K_2O per acre.

No significant yield response was obtained with M. 336 grown in sand lysimeters with four increment levels varying from 19 to 253 pounds of K_2O per acre, respectively. No significant correlation was obtained either between cane yields and the K contents of the cane leaves at different stages of growth.

The 3-month cane leaves varied from 1.54 to 2.94 percent of K, with the minimum and maximum applications of potash, respectively.

RESUMEN

Se informan en este trabajo distintos aspectos sobre: los minerales potásicos, el contenido total de potasa de algunos perfiles, los valores mínimos y máximos de la potasa asimilable, el promedio de potasa asimilable extraído por un por ciento de ácido cítrico y por el sorgo enano, en pruebas con tiestos, todo en relación con algunos grupos de suelos de Puerto Rico.

En aquellos suelos en que se encuentran los feldespatos, el promedio de potasa asimilable, extraído por el sorgo y el ácido cítrico, fué 747 y 376 libras de K_2O por acre, respectivamente. El sorgo extrajo el doble de potasa.

En los suelos sin feldespatos, el promedio de potasa asimilable extraído por el sorgo y por el ácido cítrico, fué 440 y 365 libras de K_2O por acre, respectivamente.

Se concluye, que los métodos químicos no siempre resultan confiables para determinar con exactitud la cantidad de potasa que las plantas absorben del suelo.

La caña de azúcar generalmente ha respondido poco a las aplicaciones de los abonos potásicos en Puerto Rico.

Los mayores rendimientos de la variedad P.O.J. 2878 se obtuvieron en las primeras cinco cosechas consecutivas en un suelo ácido de Puerto Rico, con una aplicación mínima de 90 libras de K_2O por cosecha, por año. La sexta cosecha al igual que las otras tres seguidas, como también el promedio de las nueve cosechas, respondieron significativamente a la aplicación de potasa en exceso a 90 libras de K_2O por acre.

No hubo resultados significativos en los lisímetros de arena con cuatro niveles de aumento, los cuales variaron desde 19 hasta 253 libras de K_2O por acre, respectivamente. Tampoco, hubo correlación significativa entre los rendimientos de la caña y el contenido de potasa de sus hojas, en las cuatro épocas distintas en las cuales se hicieron las observaciones.

A los 3 meses el contenido de potasa en las plantas de caña varió entre 1.54 y 2.94 por ciento de K, respectivamente, en las aplicaciones mínimas y máximas de potasa.

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