Potassium-Supplying Capacity of Six Upland Mollisols from PuertoRico[1,2]

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ABSTRACT

The capacity of the most important upland Mollisols of Puerto Rico to supply K to plants was determined in pots that were cropped intensively with pangolagrass for 4 years. Exchangeable K was a reliable predictor of the long term K-supplying capacity of the udic Mollisols, whereas HNO_3-extractable K was a reliable index of the long term K-supplying capacity of the ustic Mollisols.

Uptake of K from Mollisols formed under an udic-moisture regime averaged 90, 75 and 55 kg/ha/yr during the last 3 cropping years, respectively. Release patterns indicated that 50 kg of K/ha/yr probably represents the long term capacity of this group of soils to supply K to grasses. During the 4-year cropping period, 80% of the total "available" K determined in udic Mollisols at the beginning of the experiment was removed by the grass. Uptake of K from Mollisols formed under an ustic moisture regime averaged 315, 270, and 175 kg/ha/yr during cropping years, 2, 3 and 4, respectively. Release patterns indicate that the long-term K-supplying capacity of this group of soils is about 140 kg of K/ha/yr. During the 4-year cropping period, 70% of the total "available" K determined in the ustic Mollisols at the beginning of the experiment was removed by the grass.

INTRODUCTION

There are about 80,000 ha of Mollisols in the humid region (udic moisture regime) of Puerto Rico. These include the Colinas, Santa Clara, Sóller and Naranjo series derived from medium-hard Tertiary limestone, and the Durados, Toa and Estación series derived from alluvial sediments. In the semi-arid region (ustic moisture regime) Mollisols occupy about 50,000 ha. They include the Ensendada, Aguilita, Yauco, Tuque, Guanábano and Pozo Blanco series derived from soft to medium-hard limestone, and the San Antón, Coamo, Cortada, Cuyón, Jacaguas and Cintrona series derived from alluvial and estuarine deposits (6, 10).

In the humid region, the Colinas, Santa Clara and Sóller soils are mainly used for grazing; the Toa and Estación, for rice and sugarcane; and the Durados, for coconut and grasses.

The Mollisols of the semi-arid region are planted to various crops. In the Santa Isabel area, 90% of the San Antón, Coamo and Cortada soils are planted to vegetables, pigeon peas and sugarcane. The Cuyón and Jacaguas soils, which are shallow, are used primarily for rangeland. On lowland areas, Cintrona soils are affected by salts and about 90% of the

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reclaimed area is planted to sugarcane.

Research has shown that coffee (2), sugarcane (11), plantains (4), and grasses (12) take up large quantities of K and when grown on Ultisols and Oxisols respond to applications of this nutrient. Considerable information is available on the K-supplying power of Ultisols, Oxisols and Inceptisols of Puerto Rico (1, 3). On the other hand, there is no information on the K-supplying power of the upland Mollisols of Puerto Rico.

This paper presents the results of a 4-year greenhouse experiment which determined the capacity of the six most important upland Mollisols of Puerto Rico to supply K to pangolagrass.

MATERIALS AND METHODS

Soil was taken from surface and subsoils at 24 sites of Mollisols of the humid region (udic) and at 15 sites of Mollisols of the semi-arid region (ustic). The number of sites sampled was in proportion to the area covered by each soil series and ranged from 14 for the Coamo soil to 3 for the Yauco. Each site was considered a replicate.

Air dried soil (15 kg) from each site was placed in 12-liter glazed pots with a surface area of 500 cm^2. The ratio of surface to subsoil was in proportion to the thickness of the layers as they occurred in each sampling site. These values were used to convert pot data into per hectare basis.

Phosphorus (as triple super) was applied at the rate of 110 kg/ha once yearly and N (as urea) at the rate of 670 kg/ha/yr divided in equal applications, one after each of 6 cuttings. No lime was applied because all soils had pH values above 7.0.

Pangolagrass was planted in all pots and the experiment began when a solid strand was established. The grass was cut every 2 months, dried, weighed, analyzed for K content by flame photometry and the amount of K extracted was determined.

All pots were thoroughly watered twice weekly by flooding for 2 hours. Excess water was then drained from each pot and later used to irrigate the same pot. The irrigation water initially contained less than 2 p/m of K.

Soil samples were taken from each pot at the beginning and end of the experiment and analyzed for exchangeable and HNO_3-soluble K (9). Soil K data were correlated with K extracted by the grass through regression analyses.

RESULTS AND DISCUSSION

UPTAKE OF SOIL POTASSIUM BY PANGOLAGRASS

The ustic Mollisols initially contained almost 3 times as much exchangeable and 4 times as much HNO_3-soluble K as did the udic group.

Within the udic group, exchangeable and HNO_3-soluble K were lowest in Colinas soil, and were almost identical in Santa Clara and Sóller soils (table 1).

Within the ustic group, exchangeable K contents were similar among the soils, but HNO_3-soluble K contents varied widely. The amount of K extracted by pangolagrass followed the order of "available" K content of the soils, e.g., Coamo, Yauco, and Aguilita.

Over the 4-year period, pangolagrass extracted on the average 3 times as much K from the ustic than from the udic Mollisols. The grass extracted 80% of the total "available" K (exchangeable + HNO_3-soluble) from the udic group, and 70% from the ustic group.

At the end of 4 consecutive years of cropping, the udic Mollisols as a group contained an average of about 50% as much exchangeable, and 90% as much HNO_3-soluble K as did the original soil (table 1). The Colinas series had essentially the same amount of total "available" K (exchangeable + HNO_3-soluble K) as at the beginning of the experiment, but the Sóller and Santa Clara soils had lost around 45% of the original total "available" K.

At the end of the experiment, the ustic Mollisols had an average of about 25% as much exchangeable K and 65% as much HNO_3-soluble K as did the original soil. These data are similar to those reported for upland Inceptisols of Puerto Rico (1).

During the 4-year cropping period the udic Mollisols released 80%, and the ustic 70%, of the total available K determined initially yet contained 70% and 50%, respectively, as much of these forms of K at the end of the experiment. This fact indicates that these soils have a K pool, either in the fine sand and silt fractions (as feldspars), or contain appreciable amounts of micaceous clay minerals. The mineralogical data available for the soils studied (5, 7) show that the Aguilita and Sóller soils do not contain feldspars in the silt or fine sand fractions.

Patterns of curves for cumulative uptakes (fig. 1) are similar for the individual udic Mollisols, but the Santa Clara soil released about twice as much K as the Colinas or Sóller soils.

Cumulative uptake (fig. 2) for individual ustic Mollisols varied widely. The Coamo soils released about twice as much K as the Aguilita, and 40% more than the Yauco soils. In both groups, udic and ustic Mollisols, the rates of release were very rapid during year 1, tapering steadily during successive years. The high uptake during the first year is probably due to luxury consumption of abundant exchangeable K by the grass.

Cumulative uptake curves (fig. 3) were similar for udic Inceptisols, upland Ultisols and udic Mollisols.

The ustic Mollisols and Inceptisols had a much higher K-supplying power than the udic counterparts, the upland Ultisols or Oxisols. The

TABLE 1.—*Potassium status of six Mollisols before and after 4 years of continuous cropping with pangola grass in pots*

Soil series	Sites studied	K in soil at start of the experiment			K extracted by pangola grass	K in soil after 4 years of cropping		
		Exchangeable K	HNO_3 extractable K	Total available K		Exchangeable K	HNO_3 extractable K	Total available K
	Number				*kg/ha*			
Udic								
Colinas								
Eutropeptic Rendolls	14	220	280	500	360	140	380	520
Sóller								
Eutropeptic Rendolls	5	390	320	710	440	170	220	390
Santa Clara								
Eutropeptic Rendolls	5	390	310	700	730	200	210	410
Average for Udic group		330	300	630	510	170	270	440
Ustic								
Coamo	7	880	1950	2830	2110	160	1010	1170
Typic Argiustolls								
Aguilita	5	850	600	1450	860	200	700	900
Yauco								
Typic Calciustolls	3	910	1020	1930	1380	280	700	980
Average for Ustic group		880	1190	2070	1450	210	800	1010

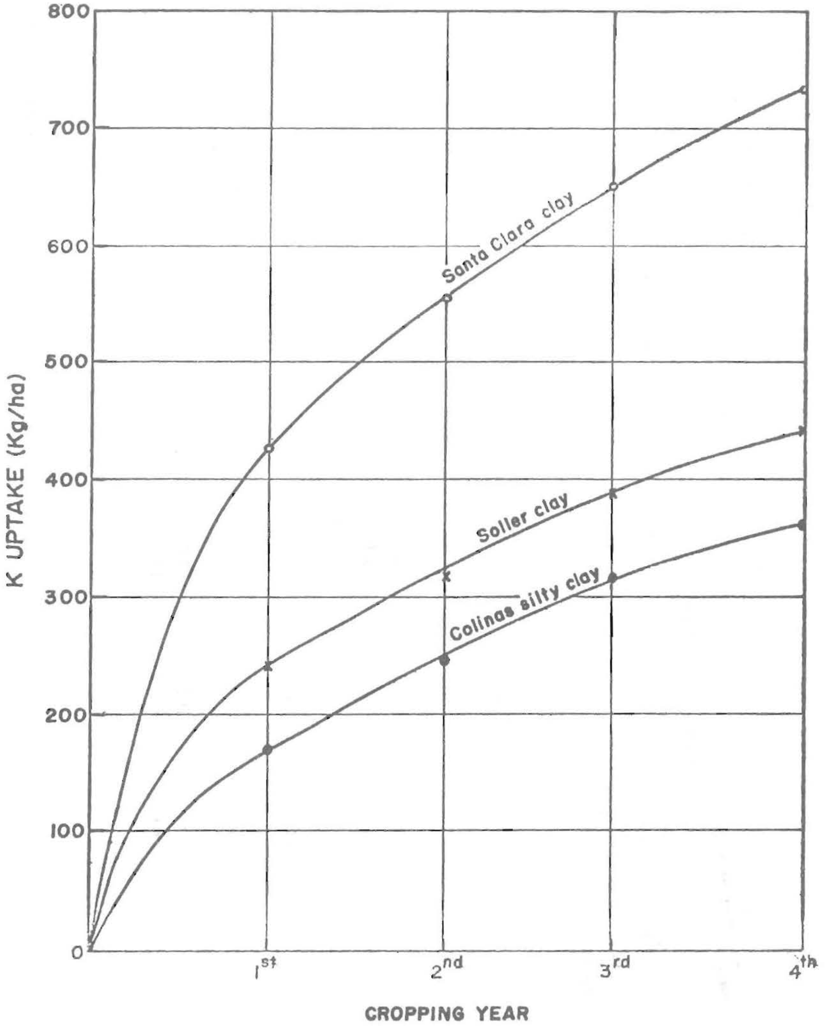

FIG. 1.—Cumulative K uptake by pangolagrass from three udic Mollisols over 4 years.

ustic Mollisols released more K than did the ustic Inceptisols although the latter have K-feldspars in the coarse separates and illite in the clay fraction (7). Ustic Mollisols have no K feldspars in the coarse fractions, so micaceous clay minerals are the probable source of their reserve K.

The large quantities of K extracted from the various udic Mollisols during year 1 (fig. 4) averaged 43% of the total available K and 54% of the K taken up during the 4 years of cropping. Uptake dropped off sharply during year 2 and only very gradually during years 3 and 4. The

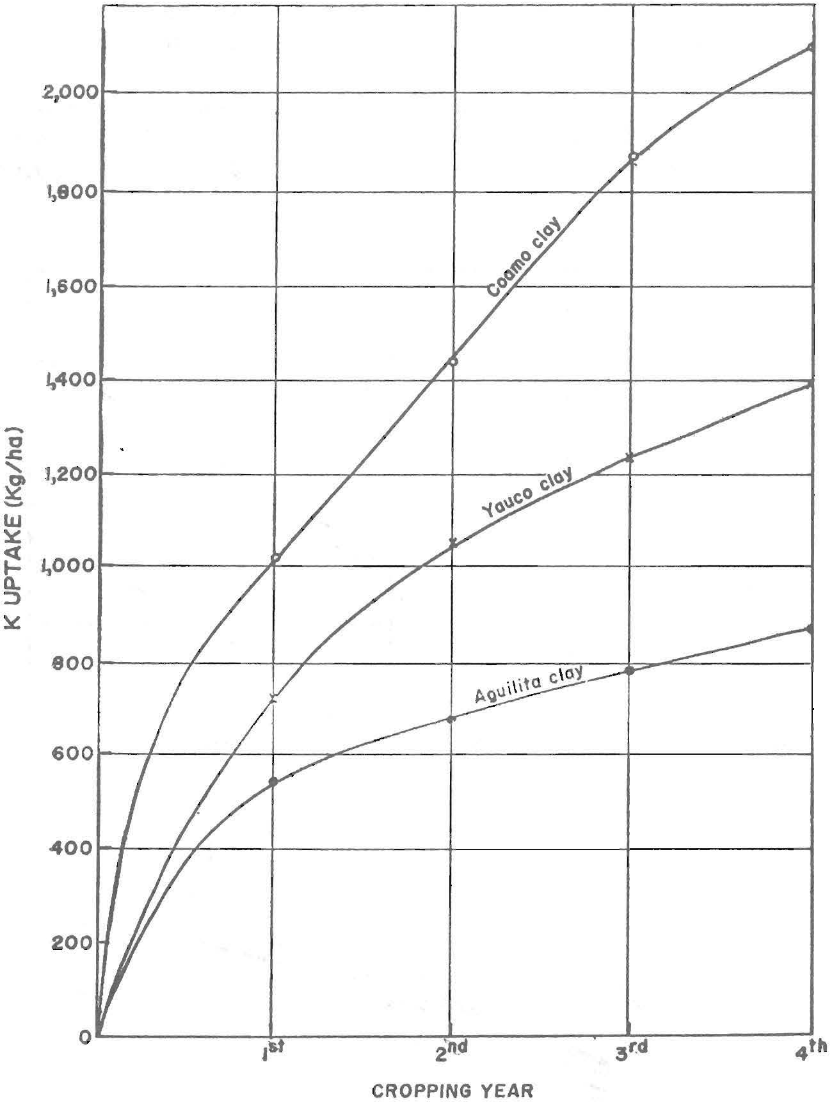

FIG. 2.—Cumulative K uptake by pangolagrass from three ustic Mollisols over 4 years.

Santa Clara soil released the largest amount of K averaging 127, 96 and 80 kg/ha during years 2, 3 and 4, respectively.

The udic Mollisols as a group (fig. 5) released an average of 90, 75 and 55 kg/ha during 2, 3 and 4 years, respectively. The release pattern indicates that the long term K-supplying power of these soils was about 50 kg/ha/yr, which is similar to that of upland Ultisols (3).

The ustic Mollisols released much more K than the udic (fig. 5). Release by ustic Mollisols was high during year 1, but dropped sharply during year 2 and decreased slowly thereafter.

The quantity of K released varied considerably among the three ustic Mollisols (fig. 6). For the Coamo soil, release was 1,000 kg/ha during year 1, dropped to 430 kg/ha during years 2 and 3, and to 250 during

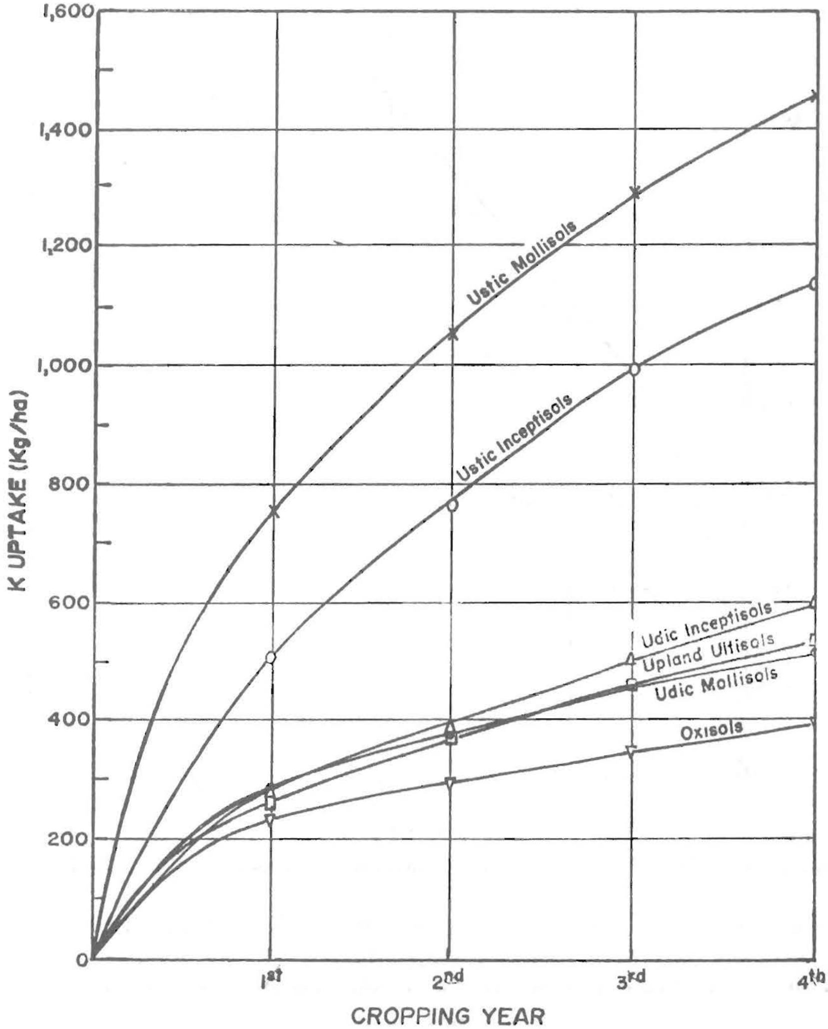

FIG. 3.—Cumulative K uptake by pangolagrass from various soil orders over 4 years. Data for Inceptisols and Oxisols from Abruña (1980) and Abruña et al. (1976), respectively.

year 4. Release from the Aguilita soils was 540 kg of K/ha for year 1, and 130, 110 and 80 kg/ha for years 2, 3 and 4, respectively.

The ustic Mollisols as a group (fig. 6) released an average of 176 kg/ha of K during year 4 but the actual release pattern, compared to the calculated one, indicates that the long term K-supplying power of this group was around 140 kg/ha, or about 25% more than that of ustic Inceptisols (1).

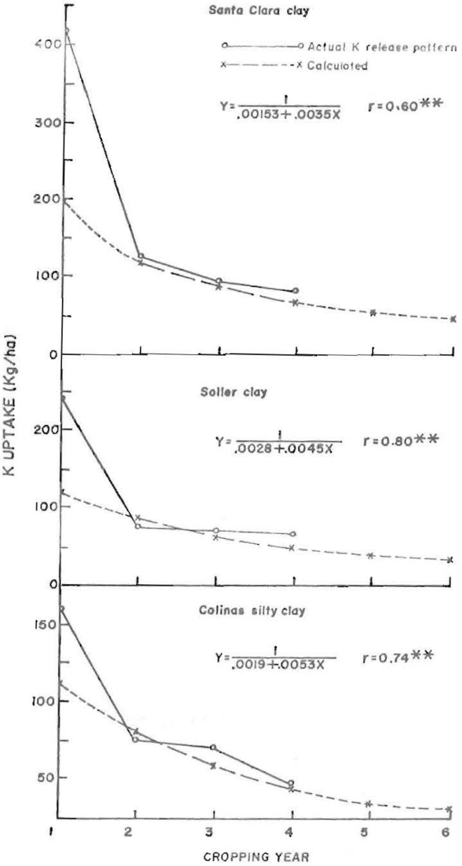

FIG. 4.—Actual and calculated K release patterns for three udic Mollisols cropped with pangolagrass over 4 years.

During year 1 of cropping, both ustic and udic Mollisols released about 40% of the total available K and 50% of the total K extracted by pangolagrass over 4 years. During the years 2, 3 and 4 both groups (udic and ustic Mollisols) released, respectively, an average of 15, 12 and 9%

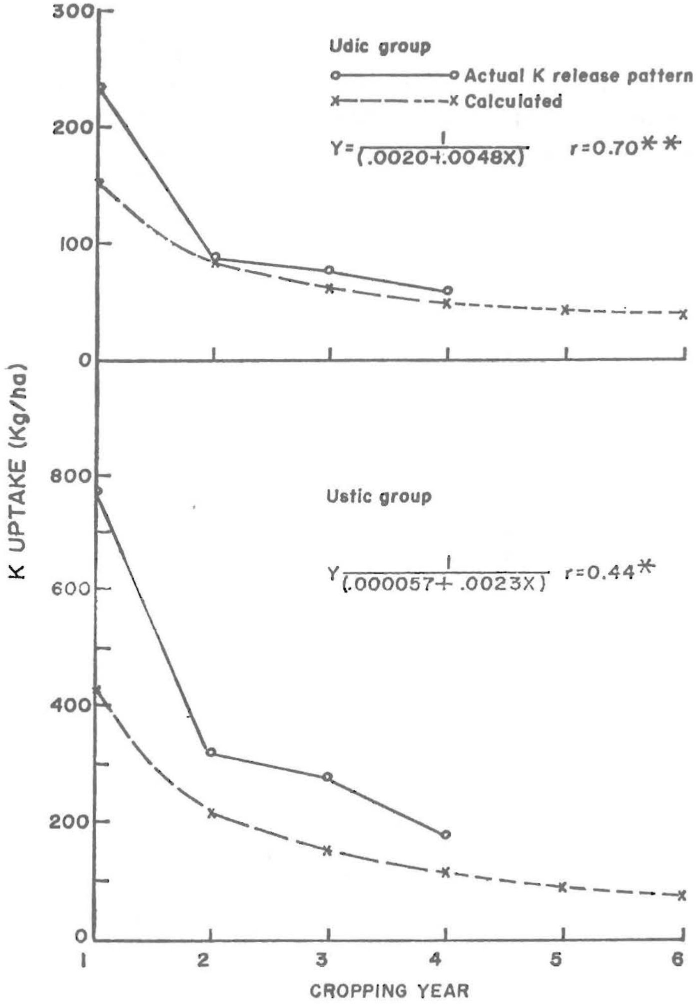

FIG. 5.—Actual and calculated K release patterns for udic and ustic Mollisols cropped with pangolagrass over 4 years.

of total available K, and 20, 16 and 11% of the K extracted by the grass over 4 successive years (table 1 and fig. 5).

Potassium content of the forage during the first year averaged 0.70% for the udic and 1.53% for the ustic group. During year 4, the K content of the forage dropped to 0.29% for the udic and .48% for the ustic Mollisols (table 2). Oliveira et al. (8), working with soils from southern Brazil, found that the K content of ryegrass grown on Mollisols dropped below 2% only after 7 cuttings; in other soil orders K content dropped to 0.4%. Under field conditions signs of severe K deficiency occur when the

K content of forage is below 0.6%; however, in this pot experiment no signs of K deficiency were evident in spite of the low K content of the forage. The stable moisture regime in pots, in contrast with drying and wetting cycles under field conditions, might be an explanation of this anomaly.

On the other hand, exchangeable K content of the udic Mollisols as a group was significantly correlated (.01 level) with uptake for year 1 and with average K uptake during the last 3 cropping years (table 2).

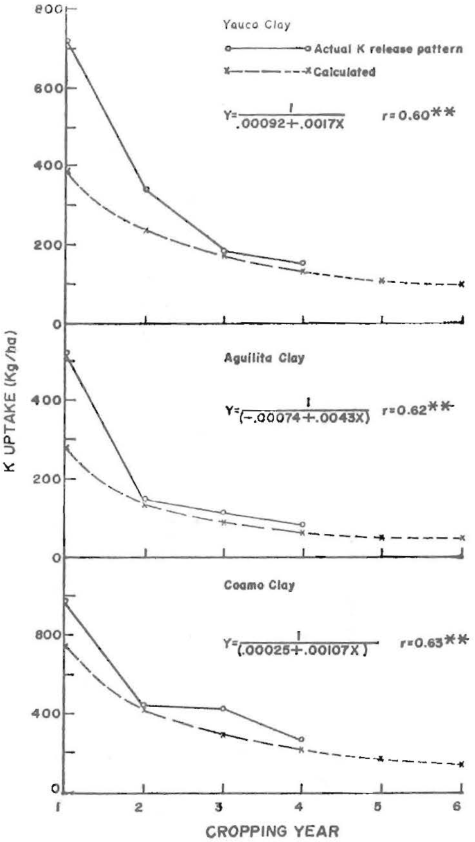

FIG. 6.—Actual and calculated K release patterns for three ustic Mollisols cropped with pangolagrass over 4 years.

Among the ustic Mollisols, Coamo and Yauco showed significant correlations between soil K values and plant uptake. In the Coamo soil, HNO_3-soluble K was significantly (.01 level) correlated during the first year and with average uptake during the last 3 cropping years. Correlation was also significant (.01 level) between available K in soil (exchangeable

TABLE 2.—*Relationship between various soil K values and uptake of this nutrient by pangola grass during a 4-year cropping period in pots*

Soil series	Exch. K vs. uptake during year 1	Exch. K vs. average K uptake for last 3 years	HNO_3-soluble K vs. uptake during year 1	HNO_3-soluble vs. average uptake for last 3 years	Total available vs. total K uptake in 4 years
			Udic suborder		
Colinas	Not significant	Not significant	Not significant	Not significant	Not significant
Sóller	Not significant	Not significant	Not significant	Not significant	Not significant
Santa Clara	Not significant	$r = .97^{**}$[1] $Y = 16.37 + .218\ X$	Not significant	Not significant	Not significant
			Ustic suborder		
Coamo	Not significant	Not significant	$r = .79^{**}$ $Y = 628.14 + .191\ X$	$r = .90^{**}$ $Y = 127.44 + .125\ X$	$r = .96^{**}$ $Y = 371.95 + .615\ X$
Aguilita	Not significant	Not significant	Not significant	Not significant	Not significant
Yauco	Not significant	$r = .98^{**}$ $Y = 87.59 + .127\ X$	$r = .99^{**}$ $Y = 32.04 + .734\ X$	$r = .99^{**}$ $Y = 43.56 + .74\ X$	$r = .98^{**}$ $Y = 282.52 + .529\ X$
Udic group	$r = .72^{**}$ $Y = 12.103 + .777\ X$	$r = .66^{**}$ $Y = 30.787 + .43\ X$	Not significant	Not significant	Not significant
Ustic group	Not significant	Not significant	$r = .82^{**}$ $Y = 435.38 + .269\ X$	$r = .92^{**}$ $Y = 57.322 + .49\ X$	$r = .95^{**}$ $Y = 48.687 + .675\ X$
Both groups	$r = .80^{**}$ $Y = 76.071 + .708\ X$	$r = .59^{**}$ $Y = 34.914 + .203\ X$	$r = .83^{**}$ $Y = 200.71 + .362\ X$	$r = .92^{**}$ $Y = 34.841 + .156\ X$	$r = .95^{**}$ $Y = 61.118 + .67\ X$

[1] Significant at the .01 level.

+ HNO_3-soluble K) and total K uptake by grass over the 4 cropping years. In Aguilita soils, potassium uptake by pangolagrass and soil K were not significantly correlated. HNO_3-soluble K content of Yauco clay was highly ($r = .99$) correlated with K uptake for year 1 and with average K uptake over the last 3 years. Exchangeable K was closely ($r = .98$) correlated with average K during last 3 cropping years. Similarly, total available K was closely correlated with total K uptake over the 4-year period (table 2).

The HNO_3-soluble K contents of the ustic Mollisols as a group were significantly correlated (.01 level) with uptake of K by the grass during the first year and with average uptake during the last 3 cropping years. Also, total K uptake for the 4-year cropping period was highly correlated with total available K. All soil K values correlated with uptake when udic and ustic Mollisols were grouped together (table 2). The fact that K extracted from the udic Mollisols was correlated only with exchangeable K values indicates that K-bearing feldspars are absent in these soils derived from limestone. On the other hand, the ustic group showed close correlations between HNO_3-soluble K and uptake by the grass, especially during the last 3 cropping years, indicating the presence of K-bearing minerals.

It can be concluded that the udic Mollisols derived from Tertiary limestone, under wet tropical conditions, can supply on a long-term basis about 50 kg of K/ha/yr to grasses. Responses to applied K, however, might be expected of those calcareous soils because of antagonism between native K and the excess Ca ions in the soil solution.

Although two of the ustic Mollisols soils studied are derived from limestone, the semiarid climate under which they were formed apparently enhanced the accumulation of K by curtailing the breakdown of K bearing minerals and the subsequent leaching. The Coamo soils are derived from alluvial sediments from the ustic Inceptisols of the southern uplands that are rich in illite and K feldspars. The long term K-supplying power of these soils is about 140 kg of K/ha/yr.

Exchangeable K values are a fairly reliable means of predicting the long term K-supplying power of the udic Mollisols, whereas HNO_3-extractable K values are fairly reliable predictors of the long term K-supplying power of the ustic Mollisols.

RESUMEN

Se determinó la capacidad de seis suelos Mollisol, tres de la altura semiárida y tres de la región montañosa húmeda de Puerto Rico, para suplir K al pasto pangola. El estudio que duró 4 años, se hizo en tiestos.

Ambos grupos de suelos suplieron grandes cantidades de K durante el

primer año. Del segundo al cuarto año las cantidades de K extraídas por el pasto fueron de 90, 75 y 55 kg/ha, respectivamente, en los suelos de la región húmeda y de 315, 270 y 175 kg/ha en los de la región árida.

Las curvas de liberación del potasio indican que 50 y 140 kg/ha y año, probablemente representan a largo plazo, la capacidad respectiva de los Mollisol de la altura húmeda y de la región semiárida para suplir este nutrimento.

Durante los 4 años que duró el experimento el 80% del K disponible en los Mollisol de la altura húmeda y 70% en los de la región semiárida fue extraído por el pasto.

Tal parece que el K cambiable es un buen índice para determinar la capacidad de los Mollisol de la altura húmeda para suplir K a largo plazo al pasto pangola, mientras que el K extraído con HNO_3 parece ser más apropiado en el caso de los Mollisol de la región semiárida.

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