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UCLA - 12 - 8 82

CONF-740801--1

UNIVERSITY OF CALIFORNIA, LOS ANGELES

LABORATORY OF NUCLEAR MEDICINE AND RADIATION BIOLOGY

CONTRACT NO. AT (04-1) GEN-12

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POTASSIUM RELEASE FROM SOME SEMI-ARID REGION SOILS

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INTRODUCTION

It is almost axiomatic that arid and semi-arid region soils are abundantly supplied with potassium. Partly for this reason, many more studies have been conducted on soil potassium in subhumid and humid regions where potassium deficiency is more common. In some semi-arid regions, such as Southern California, cropping of certain soils has been going on for over 100 years and it is not surprising that potassium deficiencies are beginning to appear. More information is needed on the potassium-supplying ability of soils for semi-arid regions and means of characterizing the potassium status of these soils.

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These studies were supported by Contract AT(04-1) GEN-12 between the Atomic Energy Commission and the University of California, and the California Agricultural Experiment Station.

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PROCEDURES

Soils. Surface (20 cm) samples of eight soils expected to display a range in potassium characteristics were selected for study involving intensive cropping, and mineralogical and chemical characterization. The soils selected were the following, listed by series name:

Bettaravia sandy loam is a transported soil derived from sedimentary parent material, developed in a terrace location and having a durapan.

Coachella very fine sand is a valley soil, having no profile development, formed from wind-modified granitic alluvium.

Elder loam is a valley soil, without profile development, developing from sedimentary parent material.

Garey sandy loam is from a terrace location, exhibiting strong profile development, developing from sandy, mixed, wind-modified alluvium.

Metz sandy loam is a valley soil, with no profile development, developing from mixed alluvium.

Pleasanton sandy loam is a terrace soil, having moderate profile development, developing from sedimentary rock alluvium.

Pleasanton very fine sandy loam.

Sorrento sandy loam is a valley soil, showing no profile development, developing from sedimentary rock alluvium.

Average annual rainfall for the areas from which the soils come is less than 650 mm and for most of the series about 500 mm or less.

Cropping studies. Air dried samples of the soils were treated with VAMA* to produce stable aggregates as described elsewhere (Lunt, Kaempffe, Youngner, 1964).

*Copolymer of vinyl acetate and maleic anhydride. Formerly sold under the name of krilium.

Fifteen hundred grams of the soil thus prepared were placed in containers 18 cm in height having draining holes. The surface area was 84 cm². The soils received 65 ppm phosphorus from single super phosphate, 150 ppm nitrogen from urea formaldehyde, and 5 ppm zinc from zinc sulfate. One series of treatments received no added potassium while the other received 500 ppm potassium from potassium sulfate. Irrigation was with tapwater (about 4 m.e. per liter of sodium, calcium and magnesium salts) using the weighed pot technique. Water applied was adjusted to provide about 20 percent leaching after the plants had become established. Each second irrigation, the tapwater was enriched with 2 m.e. per liter of calcium nitrate and 5 ppm iron from EDDHA*. It is believed that no nutrient would be limiting except, possibly, potassium. Each of the two potassium series for the eight soils was replicated four times, making a total of 64 containers. The pots were seeded to *alta fescue* (*Festuca arundinacea*) and maintained in a greenhouse where night temperatures were about 13 to 15°C and day temperatures were about 27 to 30°C. Grass was clipped to a height of 5 cm when heights were about 7 to 9 cm. All clippings were saved for weighing and analysis. At the intervals indicated on the figures (under Results and Discussion) about 10 grams of soil were obtained from each container by small diameter cores taken to a depth of 10 cm (the surface 2 centimeters were discarded) and used for chemical analysis after air drying. The cores were replaced by original soil. Care was taken not to remove cores from a location previously sampled.

Analytical procedures. A. Mineralogical characterization of the clay fraction was done by x-ray diffraction following approximately the procedures

*ethylene diamine di(orthohydroxy)phenyl acetate

developed by Jackson (1956). Quantitative estimates in parts per ten of the clay fraction were obtained for kaolinite, montmorillonite, illite, and chlorite. In addition, the relative abundance of accessory clay-size quartz, plagioclase, and feldspar was obtained. B. Plant analyses were done by flame photometry after digestion of plant material by nitric and perchloric acid. C. Soil chemical analysis: Exchangeable potassium was measured by shaking 10 g of soil with 200 ml of 1 N NH_4OAc , pH 7, followed by filtration, washing, and measurement by flame photometry. The superiority of NH_4OAc as an extractant for potassium was demonstrated by Merwin and Peach (1951).

Boiling nitric acid was also used to extract potassium from samples taken prior to cropping. In this procedure 2.5 g of soil were boiled for 10 minutes in 1 N HNO_3 then washed with 0.1 N HNO_3 to give 100 ml and then measured by flame photometry (DeTurk et al, 1943).

Cation exchange capacity and clay content of soils were determined by well established procedures.

An additional effort to characterize the potassium-supplying ability of the soil involved ball-milling the whole soil to pass 270 mesh per inch screen, followed by extraction with ammonium acetate as described above.

RESULTS AND DISCUSSION

The results of mineralogical and chemical characterization of the soils used in the study are summarized in Table 1. The data were obtained prior to cropping. The yields as a function of time for the potassium fertilized and unfertilized treatments are presented for six soils in Figures 1 through 6. The exchangeable potassium found in each soil at

various intervals is also presented in the figures. For brevity, the responses on the Metz and Sorrento soils are omitted. The response curves for both these soils resembled that of the Elder soil. Table 2 summarizes yield response with reference to the potassium fertilized plots for each soil, along with other pertinent data. The assumption is made that potassium found in the roots and stubble below the clipping height is approximately constant during this period. This assumption could not have been made for comparisons dating from the time of seeding.

The alta fescue produced on four of the soils responded to added potassium while no significant response was obtained on the other four soils. It should be stressed that the cropping treatment was intense, due to favorable environmental and light conditions. On an acre basis, dry weight production for the 21-week period was of the order of 5 to 6 tons per acre. Thus, deficiencies occurring under these conditions may not have occurred in the field.

It should be noted that all of the soils deficient in potassium were from terrace locations and, presumably, have been in place for a millenium or more. The more advanced stage of weathering of the terrace soils is indicated by the rather large proportion of kaolinite in the clay fraction although the Pleasanton sandy loam is somewhat anomalous in this regard.

The data on plant accumulation of potassium is very instructive. The Elder, Coachella, and Sorrento supplied about 400 mg or more for the 21-week period, whereas, the accumulation from the Metz was less than half that amount although adequate for maximum growth. It is particularly noteworthy that most, if not all, of the accumulated potassium is attributable to non-exchangeable sources. Black (1968; p 667 et seq.) reviews other work

showing similar phenomena. Biotite and illite have been shown to release potassium readily to plants from non-exchangeable sources when plant roots reduce soil solution concentrations of potassium below critical levels. In the absence of growing plants, these losses substantially stop. Unfortunately the mineralogical analysis did not include biotite. The mineralogical analysis is very instructive in reference to the potassium-supplying ability of the soil. The three soils supplying potassium readily contained relatively large amounts of illite and chlorite; however, the Pleasanton sandy loam contained relatively large amounts of illite but was deficient. This indicates that not all illite (presumably more weathered illite) is necessarily a rich source of potassium. This pattern would be consistent with vermiculite which may effectively "fix" potassium (Page et al. 1963). Reitemeier et al. (1951) have discussed problems of correlating potassium uptake with mineralogical analyses.

Given the significance of non-exchangeable potassium in supplying plants, it is not surprising to note that exchangeable potassium levels are not reliable for predicting potassium supply to plants. The Coachella and Metz both had exchangeable potassium levels in the general range of those found in the deficient soils. Percentage potassium saturation was not a dependable reflection of potassium supply. Ammonium acetate extraction of pulverized soil material showed some consistent relationships in that all deficient soils released less than 300 mg per 1500 grams, while the potassium adequate soils released more. Boiling nitric acid extraction is the most convenient and seemingly reliable of the characterization methods. Values of approximately 1400 mg potassium per 1500 g soil were associated with adequate supply, while values of about 1000 or less were associated with deficiency.

SUMMARY

Intensive cropping, under greenhouse conditions, of eight southern California soils distinguished four soils deficient in potassium from four soils sufficient in potassium. Deficient soils were all from terrace locations. Sufficient soils were younger, valley soils. Plant accumulation came from both non-exchangeable and exchangeable sources. In some cases, non-exchangeable potassium was apparently the exclusive source. Deficient soils were notable for their low release of non-exchangeable potassium and low levels of exchangeable potassium. Soils releasing large quantities of non-exchangeable potassium contained 1.7 to 2.4% illite plus chlorite. Boiling nitric acid extraction of potassium appears satisfactory for characterizing soils.

Zusammenfassung

Durch intensive Nutzung von acht suedkalifornischen Boeden unter Gewaechshausbedingungen konnten vier kaliumreiche von vier kaliumarmen Boeden unterschieden werden. Kaliumarme Boeden kamen alle von Hangterassen. Die kaliumreichen Boeden waren juengere Ablagerungen am Boden von Taelern. Das Kalium der Pflanzen kam von nicht austauschbaren und austauschbaren Quellen in den Boeden. In manchen Faellen war offensichtlich nicht austauschbares Kalium die einzige Quelle. Kennzeichnend fuer kaliumarme Boeden war die geringe Freisetzung von nicht austauschbarem Kalium und die niedrigen Spiegel von austauschbarem Kalium. Boeden, die grosse Mengen von nicht austauschbarem Kalium freisetzten, enthielten 1,7 bis 2,4 % Illit und Chlorit. Die Extrahierung von Kalium mit kochender Salpetersaeure erwies sich als befriedigend zur Charakterisierung von Boeden.

La culture intensive sous serre de huit sols de la Californie du sud a permis de distinguer quatre sols déficients en potassium de quatre sols adéquatement pourvus potassium. Tous les sols déficients provenaient de terrain en terrasse. Les sols adéquatement pourvus étaient jeunes, des sols de vallée. L'accumulation de potassium dans les plantes provient à la fois de sources échangeables et non-échangeables. Dans certaines cas, le potassium non-échangeable était apparemment la source exclusive. Les sols déficients étaient remarquables par leur libération lente de potassium nonéchangeable et leur bas niveau de potassium échangeable. Les sols capable de libérer des quantités importantes de potassium non-échangeables contenaient de 1,7 à 2,3% d'illite plus chlorite. L'extraction du potassium par l'acide nitrique bouillante apparaît satisfaisante.

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	CEC <u>m.e./100 g</u>	Original <u>ppm K</u>	% Sat. <u>K</u>	% <u>Clay</u>	<u>Clay minerals ppt</u>				Accessory Clay Size Minerals ¹
					<u>Kao.</u>	<u>Mont.</u>	<u>Illite</u>	<u>Chlorite</u>	
Coachella V.F. Sand	6.80	60	2.3	3	1	3	5	1	1,2,3
Elder Loam	22.35	552	6.3	17	2	7	1	0	1,2,3
Sorrento Sandy Loam	11.55	186	4.1	6	5	1	4	0	1,2,3
Metz Sandy Loam	7.55	70	2.4	3	6	2	1	1	1,3,2
Bettaravia Sandy Loam	5.80	64	2.8	3	8	1	1	0	1,2,3
Pleasanton Sandy Loam	8.95	38	1.1	4	4	2	4	0	1,2,3
Garey Sandy Loam	6.55	56	2.2	7	9	1	0	0	1,2,3
Pleasanton V.F. Sandy Loam	9.05	42	1.2	6	6	3	1	0	1,2,3

Table 1. Chemical and mineralogical characterization of soils used in this study prior to cropping.

¹Listing in order of abundance

1. Quartz
2. Plagioclase
3. Feldspar

	CEC <u>m.e./100 g</u>	Original <u>ppm K</u>	% Sat. <u>K</u>	% <u>Clay</u>	<u>Clay minerals ppt</u>				Accessory Clay Size Minerals ¹
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Coachella V.F. Sand	6.80	60	2.3	3	1	3	5	1	1,2,3
Elder Loam	22.35	552	6.3	17	2	7	1	0	1,2,3
Sorrento Sandy Loam	11.55	186	4.1	6	5	1	4	0	1,2,3
Metz Sandy Loam	7.55	70	2.4	3	6	2	1	1	1,3,2
Bettaravia Sandy Loam	5.80	64	2.8	3	8	1	1	0	1,2,3
Pleasanton Sandy Loam	8.95	38	1.1	4	4	2	4	0	1,2,3
Garey Sandy Loam	6.55	56	2.2	7	9	1	0	0	1,2,3
Pleasanton V.F. Sandy Loam	9.05	42	1.2	6	6	3	1	0	1,2,3

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LEGEND

Figures 1 through 6. Dry weight of clippings produced on various soils, as a function of time, on potassium fertilized and unfertilized plots. Exchangeable potassium at various intervals is also given on the figure.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.