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LOCATION OF POTASSIUM-FIXING SOILS IN THE SAN JOAQUIN VALLEY AND A PRACTICAL SOIL K TEST PROCEDURE

Brian Marsh, Stuart Pettygrove, Randall Southard, Mariya Meese, Craig Rasmussen, Donald McGahan, Jiayou Deng, Bruce Roberts, Dan Munk, and Steve Wright
University of California
Shafter, Davis, Hanford, Fresno, and Tulare, CA

Abstract

Mapping the location of K-fixing soils in the San Joaquin Valley continues. In 2001 and 2002, 33 soil profiles were sampled. They fall into three categories: Sierra Nevada coarse-textured alluvium, Coast Range coarse-textured alluvium, and fine-textured alluvium. So far, complete mineralogical assays have been made on 5 profiles. Sierra Nevada alluvium soils have high amounts of vermiculite and >60% K fixation, and fixation increases with depth; Coast Range alluvium has more chlorite and <60% K fixation. On the samples characterized so far, K measured by the sodium tetraphenyl boron method (hypothesized to extract exchangeable K and a portion of fixed K) was not consistently related to conventional soil test K, or to the source of parent material. On the other hand, K fixation measured by amount of K removed from an 18 mmol solution in a 7-day incubation was related to source of parent material.

Introduction

K fixation and its contribution to K deficiency in cotton in the San Joaquin Valley were documented in the 1960s. Research on this problem has continued up into the mid and late 1990s. A UC bulletin was issued in the late 1990s that recommends soil and plant diagnosis criteria for cotton K deficiency. In that bulletin, it is recommended that in the worst cases (low K soil test), K fixation be measured in the soils and if >60% in the 6-18 inch depth, 400 lb K_2O/acre be applied. This is very expensive and should be applied only where a strong yield response is expected. K deficiency also contributes to poor fiber quality. The UC bulletin does not address where farmers should expect to see this K fixation problem. Also methods for measuring K fixation potential are not practical for commercial agricultural laboratories. As recently as 2002, late season decline of Acala cotton, often associated with K deficiency, was observed at a number of San Joaquin Valley farms in Tulare and Kings Counties. Farmers in the San Joaquin Valley still report difficulty in "keeping the K numbers up."

The cotton-growing region of the Southern San Joaquin Valley has deep alluvial soils formed from two different parent materials, sedimentary rock of the Coast Range and granitic rock of the Sierra Nevada mountain range. The mineral weather sequence of high native K granite (biotite mica → vermiculite → smectite) first releases K then has a very high K fixation capacity and finally a low K fixation capacity. Digital soil surveys and cotton production maps can be overlaid. The objectives of the study are to determine if soil K-fixation can be predicted from soil texture and mineralogy as inferred from soil surveys and test K extraction methods for predicting K-fixation capacity on soils collected from the San Joaquin Valley.

Materials and Methods

During 2001, initial maps of coarse textured soil were produced from the USDA-NRCS SSURGO database, the project soil survey was begun, and a K fertilizer strip trial was conducted near Kerman, Fresno County. During 2002, we continued investigation of the location and mineralogy of K-fixing soils. Also in 2002, four K fertilizer trials were conducted in Kern Co. (Shafter REC), Kings Co. (two near Hanford), and Fresno Co. (south of Kerman). Soil and plant sample analysis from the 2002 fertilizer trials are not completed. This report will focus on the soil survey and laboratory K fixation test activities.

We have collected soil samples from 33 profiles representing three categories: Coarse loamy or fine loamy with coarse surface texture soils derived from granitic, Sierra Nevadan parent material (expected high K fixation potential); coarse loamy family or fine loamy with coarse surface texture derived from coastal, non-granitic parent material (expected low K fixation potential); and finer-textured soils from either source of parent material (expected low K fixation potential).

Most of the sites were either in cotton production at the time of sampling or in a cotton rotation. Initially, sampling sites were selected based on map classes as defined above. Soil grab samples were collected from the 15-45 cm depth from a total of 48 separate fields in four counties (Fresno, Kings, Kern and Tulare) that received no K fertilizer in the fall of 2000, nor at any time during 2001-2002. In a reconnaissance survey at each site, three grab samples were collected 10 crop rows apart from each other. Surface texture was estimated by feel throughout the field, and at one of the three grab sample sites, texture was determined to a depth of 100 cm. Grab samples were brought to the laboratory, and exchangeable K^+ was extracted using 1M NH_4Cl. Locations for full profile sampling were chosen for the sites that had less than 200 mg/kg NH_4Cl-extractable K. During February- August 2002, soil samples were collected by horizons from 31 farm fields including at locations of 5 trial fields. Soil pits for profile description were dug in furrows after hand leveling cotton beds to provide a consistent reference point for depth. Selected sites representing the first soil category listed above (Sierra Nevada parent material) are mapped as Hesperia sandy loam, Grangeville fine sandy loam, Armona loam, Boggs sandy loam, Kimberlina fine sandy loam and Wasco sandy loam. Sites in the second soil category (Coast Range parent material) included Panoche loam, Kimberlina fine sandy loam, Wasco sandy loam and Milham sandy loam. Fine-textured soils sampled included Rossi clay loam, Gepford clay, Armona loam, Tulare clay, Buttonwillow clay, Panoche loam and McFarland loam.

Soil samples were separated into size fractions using a pipette method and centrifugation. Mineralogical composition of the fractions will be analyzed using a Diano XRD 8000 diffractometer producing Cu Kα radiation. The K methods (Table 1) are being performed on whole soil samples. We are testing a recently modified method for estimating plant-available K. This test, the sodium tetraphenyl boron method ($NaBPh_4$), requires a five-minute incubation and routine wet chemistry techniques. This method extracts a portion of the fixed (non NH_4OAc-extractable) K that has been shown by researchers at Purdue University to be closely correlated with plant uptake of K in greenhouse studies. The greatest advantage of the $NaBPh_4$ method is that the release mechanism of nonexchangeable K in the procedure more closely simulates the extraction of this nutrient by plant roots. Other soil properties measured include pH, CEC (NH_4OAc, pH 7), and carbonate equivalent.

Results

While much of the laboratory study of this project is ongoing, the preliminary results show that sand fractions of the soils we sampled are dominantly fine sand followed by very fine and medium sand fractions. Cation exchange capacity ranges from 5 to 13 $cmol_c\ kg^{-1}$ and is the highest in soils derived from Coast Range alluvium (Table 2). The sodium tetraphenyl boron test has been performed on a few profiles so far. The highest concentrations of $NaBPh_4$-extractable K, as well as soluble and NH_4-extractable K, occurred in the Ap horizons of the Wasco and Panoche series in Kings County. The K levels in these locations were unexpectedly high, which made us think that the sites were fertilized between the time of grab-sampling and full profile sampling. The portion of plant-available nonexchangeable K that was extracted by the $NaBPh_4$ method (defined as $NaBPH_4$-extractable K minus NH_4-extractable K) in the upper horizons was the highest in the Grangeville soil (71-82%). Preliminary mineralogical studies of clay fractions showed that smectites dominate the clay fractions of Wasco and Panoche soil series, whereas clay fractions of Grangeville and Boggs soils also contain a significant amount of biotite and some chlorite. The near absence of vermiculite suggests that clay fractions probably have a low K^+ fixation potential. We speculate that the silt and fine sand fractions may contribute to K-fixation in the Sierra-alluvium-derived soils, and we are pursuing mineralogical investigations to test this hypothesis.

Conclusions

Silt fractions of soils from Sierra Nevada source are dominated by vermiculite and mica, whereas silt fractions from Coast Range sources also contain a significant amount of chlorite. Based on K-fixation tests, coarse- and fine-loamy soils derived from Sierra Nevadan parent material fix the highest amount of added K (46-99%) especially in the deeper horizons. Soils from Coast Range alluvium fix 0-35% of added K, and fixation decreases with depth. All tests must be completed to determine whether family-level textural class is useful in identifying potential K fixation capacity. The highest concentrations of sodium tetraphenyl boron ($NaBPh_{4)}$-extractable K, as well as soluble and NH_4OAc-extractable K, occur in soils from Coast Range sources. Fine-loamy soils have the lowest levels of $NaBPh_4$-extractable K. $NaBPh_4$ alone may not be a satisfactory extractant for estimation of K – fixation.

Table 1. Summary of analytical methods for potassium study.

Method / Reagent	Form of K extracted	Procedure
K^+ Release Test (H_2O)	Soluble	7 days incubation with daily shaking for 45 min. 1:10 soil:solution ratio
1M NH_4OAc	Soluble and Exchangeable	Vacuum extraction, 1:10 soil:solution ratio
Tetraphenyl boron (0.2M $NaBPh_4$)	Plant-available K (soluble, exchangeable and some nonexchangeable)	Incubation for 5 min. Soil: extractant ratio is 1:3

Table 2. Particle size distribution, CEC and soil K levels in some soils of Kings County.

Depth, cm	Clay (%)	Silt (%)	Sand (%)	CEC, cmol*kg^{-1}	Extractable K+: H_2O mg/L	Extractable K+: NH_4OAc mg/kg	Extractable K+: $NaBPh_4$ mg/kg	Parent Material or Soil category
Wasco: Coarse-loamy, mixed, superactive, nonacid, thermic Typic Torriorthent								
0-19	15.5	18.0	66.5	12.2	12.0	516	1183	CR*
19-43	13.8	17.9	68.3	11.7	9.7	456	1053	coarse
43-85	14.8	19.4	65.8	11.0	0.8	62	272	
85-150	13.6	12.6	73.8	10.1	1.1	68	256	
Panoche: Coarse-loamy, mixed, superactive, thermic Typic Haplocambid								
0-25	14.4	18.2	67.3	12.2	15.0	622	1315	CR
25-66	12.3	16.7	71.0	11.9	1.4	108	421	coarse
66-95	13.3	18.9	67.8	12.3	0.8	70	336	
>95	15.7	19.4	64.9	12.3	0.6	75	306	
Grangeville: Coarse-loamy, mixed, superactive, thermic Fluvaquentic Haploxeroll								
0-19	12.6	16.1	71.3	7.2	7.8	178	621	SN**
19-40	12.7	16.2	71.1	7.5	4.3	105	430	coarse
40-54	10.7	17.8	71.4	7.1	2.1	49	288	
54-80	9.7	17.0	73.3	NA	1.7	42	198	
80-95	11.3	30.3	58.4	NA	4.0	42	165	
95-110	5.3	7.5	87.2	NA	NA	17	72	
110-140	5.6	2.7	91.6	NA	3.9	11	56	

* CR – Coast Range parent material
**SN – Sierra Nevada parent material

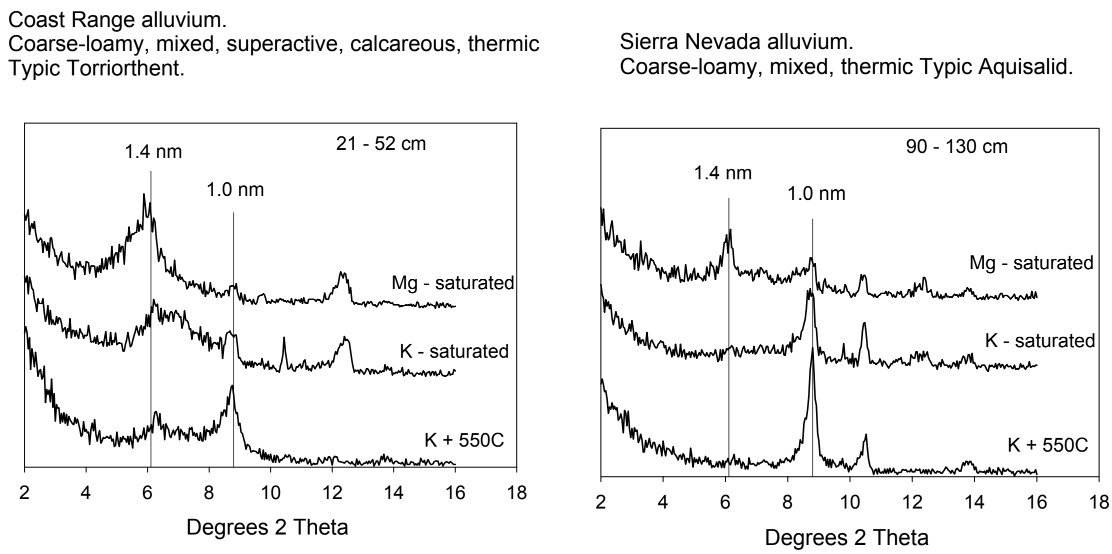

Figure 1. X-ray diffractograms of silt-sized fraction of soil developed from Sierra Nevada alluvium indicates presence of vermiculite, as indicated by complete disappearance of 1.4-nm peak when sample is K-saturated (right). Soil from Coast Range alluvium shows retention of peak upon K saturation (left) indicating possible presence of chlorite, rather than vermiculite.

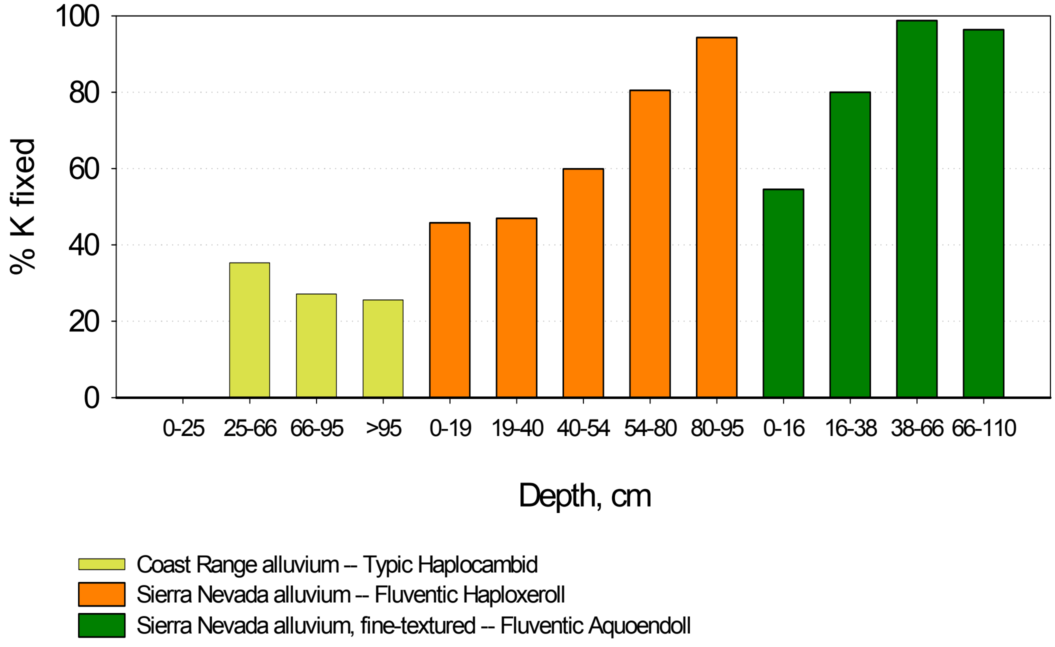

Figure 2. K fixation is higher in San Joaquin Valley soils formed in Sierra Nevada alluvium than in Coast Range alluvium.