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Downward Movement of Surface-Applied Potassium as Related to Source, Soil Type, and Water Quality

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Laboratory soil columns were utilized for comparison of four K sources—Sul-Po-Mag, KNO_3 , K_2SO_4 and Fritted Potash applied to soils differing in mineralogical composition and leached with two irrigation waters. Reduction in CEC, exchangeable plus soluble K, and K in the leachate were measured. It is evident that K status of the montmorillonitic and vermiculitic soils differed markedly. There was greatest K fixation with the latter soil. The use of Fritted Potash, when compared to more soluble K sources such as KNO_3 and K_2SO_4 , on soils which do not fix K may reduce considerably the amount of K lost by leaching. For soils which fix K in a difficultly exchangeable form, the amount of K fixed from applications of the very soluble sources.

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Downward Movement of Surface-Applied Potassium as Related to Source, Soil Type, and Water Quality^{1,2}

INTRODUCTION

FOR MANY YEARS, field and laboratory observations have shown that soils fix K in varying degrees, depending on plant availability. Many researchers have made valuable contributions to the phenomenon of K fixation chemistry in soils and clay minerals.

The conditions affecting the processes of K fixation and release, the fixation of K in various soils, and the role of clay minerals-as to species, lattice composition, and other factors-have been well established. The literature on the various aspects of K fixation is extensive. and has shown that K fixation in soils is primarily a function of their clay mineralogy. The clay minerals responsible for K fixation in soils are principally vermiculite and illite. Upon dehydration montmorillonite has also been reported to fix K. In general, the mechanism of K fixation is thought to involve the penetration of K ions into the interlayer crystal lattice followed by collapse of opposing tetrahedral faces (Barshad, 1950, 1952; Page and Bauer, 1940; van der Marel, 1954). Upon collapse the K ions (radius 1.33 A) snugly fit into the hexagonal cavities (radius 1.40–1.60 A) which are formed by oxygen atoms of adjacent tetrahedral layers. With vermiculite and illite, where the interlayer cation is K or ions of similar effective radii (Rb, Cs, NH_4), the interlayer space is not easily accessible and consequently the K is not readily replaced by other cations.

Barshad and Kishk (1968) have shown that K fixation is increased by oxidation of octahedral ferrous (Fe^{2+}) to ferric (Fe^{3+}) iron in soil vermiculites. In biotite, the oxidative reaction renders interlayer K more difficult to replace (Juo and White, 1969). Potassium fixation is not an irreversible phenomenon. Depletion of fixed K, however slow, in soils is evident regardless of their clay mineral component. Maintenance of an extremely low level of K in the ambient soil solution with salt extraction favors depletion of fixed K.

The extent to which K fixation occurs in California soils varies considerably depending on the chemical and mineralogical soil properties. These extremes in soil properties tend to yield a great variety of soils with complex distribution patterns. Yet one finds K fixation characteristics on soils derived from a wide cross-section of complex parent materials—granitic, sedimentary and mixed alluviums, and acid and basic igneous rock alluviums; on soils having recent and only moderately developed profiles; on native as well as cultivated soils—from the northern San Joaquin

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Valley to southern California. However, two unique characteristics of K fixation in these soils are not found in the southern and eastern soils of the United States. One is the preponderance of biotite-weathering products where K fixation results primarily from trioctahedral vermiculite. The other is the fact that K fixation occurs under wet conditions. Potassium fixation with a resultant concurrent interlayer contraction, as known in the south and eastern soils of the United States, is primarily associated with a wet-dry-heat reaction in soils containing montmorillonite, illite, and dioctahedral vermiculite.

A large number of papers reporting the findings of K chemistry of California soils have been published (Barshad, 1951; Bower, 1950; Bredell, 1966; Hoagland and Martin, 1933, 1935; leRoux and Coleman, 1963; Lilleland,

Columns to contain the soil were constructed in the following manner: Opaque polyvinyl chloride (PVC) tubing (Kraloy/Chemtrol Co., Santa Ana, California) with an inside diameter of 5 cm was cut into 3 cm lengths. Twelve 3 cm lengths were sealed together using Silastic Sealer (Dow Corning Corp.). A rubber stopper with a pyrex tubing insert was fixed to the bottom of the column. To prevent soil from filtering through the pyrex tube a glass wool disk, plastic screen, filter paper disk, and plastic screen were placed, in the above order, on top of the rubber stopper. A stopcock was fitted to the pyrex tube outlet to control the flow rate. The columns were held together using clamps with adjustable screws. The intact columns are shown in figure 1.

Subsurface samples 30-60 cm (depth) of Grangeville, Cajon, and Visalia soil series were used. Grangeville and Cajon soils were collected from cultivated fields near Fresno. The third soil was collected from a citrus orchard near Escondido. Grangeville and Cajon soils 1959; Martin, et al., 1945; McKinnon and Lilleland, 1931; Page, et al., 1963, 1964, 1967; Pratt and Goulben, 1957; and Stromberg, 1960). Most of these studies have emphasized the significance of K fixation or release in the field. under greenhouse conditions, or laboratory batch soil K ion exchange systems. Little information is available concerning K fixation in soil column systems. The following study was initiated to obtain quantitative data relative to the manner by which surface-applied K will distribute itself in California soils of varying chemical and mineralogical properties in soil column systems. From the information accumulated one can make certain generalizations regarding the degree to which surface-applied K will move to lower depths in soil systems that are similar to those studied.

MATERIALS AND METHODS

are derived from granitic alluvium, and Visalia soil from basic igneous alluvium. The clay minerals present in Grangeville and Cajon soils were principally biotite weathering products (vermiculite and hydrobiotite). The soils were essentially free of montmorillonite. Visalia soil contained principally montmorillonite with only traces of hydrobiotite and vermiculite.

The soils were treated with VAMA (a mixture of calcium hydroxide and a copolymer of vinyl acetate and the partial methyl ester of maleic acid, Monsanto Chemical Co.), 0.25 per cent by weight, and wet to a water content approximately equal to the moisture equivalent. They were equilibrated wet for 48 hours, air dried, and then passed through a 2 mm sieve. Approximately one kilogram of soil was packed into the column using a long-stemmed powder funnel. Special care was taken to produce a homogenous soil throughout the column. The tip of the funnel was kept near the soil surface to minimize particle-size separation. Filled soil columns



Figure 1. Arrangement of intact soil columns in position for leaching.

were uniformly packed by dropping each column 10 times from a height of two inches on folded towels on top a laboratory bench.

Soil columns were saturated with the particular water to be used by subirrigating to displace as much air as possible from the soil pores. Following saturation, a constant head of water was maintained at the surface by using the Mariotte reservoir technique. Water was permitted to drain through the column until an apparent equilibrium was reached (as determined by Ca + Mgconcentration of the leachate). Potassium was applied to the surface as either Sul-Po-Mag³ (International Minerals Corporation), KNO_3 or K_2SO_4 in amounts equal to 40 meg per column (4 meq per 100 g) for the Grangeville and Visalia soils, and 20 meq per column (2 meq per 100 g) for the Cajon soil. Potassium as Fritted Potash⁴ (Leslie-Agriform Corporation) was applied in amounts equal to 40 and 80 meq per column. (Results obtained from Fritted Potash at K levels of 40 and 80 meq per column were so similar that only data for 40 meq K/column levels are presented and discussed.) The above treatments were selected so that we could observe K movement through a finite depth in the column. Control treatments for each soil consisted of identical conditions except that no K was applied to the surface.

Following K applications of Sul-Po-Mag, KNO_3 , and K_2SO_4 , 2.75 liters of either Colorado River or Gage Canal water was leached through the column. Potassium applications of Fritted Potash were leached with 5.5 liters using

⁸ Sul-Po-Mag is a registered trademark for a commercial grade of the double fertilizer salt— K_2SO_4 ·2MgSO₄ containing 22.3 per cent K_2O and 11.25 per cent MgO.

^{*} Fritted Potash contains 29 per cent K₂O; one-half, or 14.5 per cent, is water soluble.

Colorado River water only. Chemical composition of both waters is presented in table 1. For the columns used, 2.75 and 5.5 liters were equivalent to 104 and 208 surface cm of water, respectively. Flow rate was maintained at approximately 0.5 ml per minute. Leachate was collected in 250 ml fractions and its K content determined.

After 2.75 or 5.5 liters of a particular water had passed through the column it was dismantled such that each 3 cm increment of soil was individually separated. Starting at the surface, alternate 3 cm increments of soil were analyzed in the following manner: A subsample of approximately 25 g was equilibrated overnight with approximately 25 ml of 1 N NaCl. The mixture was passed through a Buchner funnel to separate the soil from the aqueous phase. The soil pad was leached with eight 25 ml increments of 0.1 N NaCl. Each incremental volume was permitted to drain through the soil pad prior to adding the succeeding increment. The NaCl extract was diluted to 250 ml volume with distilled water and analyzed for K. The K content of the NaCl extract, expressed in meg per 100 g air dry weight of soil, was taken as the amount of soluble plus exchangeable K in the soil-water system.

Excess NaCl was removed from the soil pad by leaching with eight 25 ml increments of absolute redistilled methanol. The exchangeable Na was removed by leaching with 240 ml of 0.1 N HCl. The extract was diluted to 250 ml volume and its Na content determined. Cation exchange capacity (CEC) was computed from the Na content of the HCl extract. Differences between CEC of the controls (no K applied) and that of the K treatments was taken as the amounts of K fixed. Previous studies have established that under wet conditions for these types of soils, differences in CEC are a reliable means for the determination of amounts of K fixed.

CHEMIC	AL COMPOSITION OF COLORAI	DO RIVEF	t AND	GAGE	CANA	L WA'	rers	USEI	S NI C	OIL	COLU	I NMI	LEAC	SONIE	
	:	EC × 10°		Total	;	ء 1		Cati	SILIC				Anions		
Source	Location	at 25°C	Н	solids	8 N	ŋ	Ca	Mg	Na	K	CO3	нсо	SO4	G	80N
		mmhos/cm		mdd	per cent	mqq				pəm	per liter	L			
Colorado River 3age Canal	Lake Mathews, Riverside Citrus Research Center, UCR Riverside	1055 510	8.3 8.1	668 362	39 3 4	.12	4.15 2.44	2.29 .90	4.17 1.78	.12 .08	0 0	2.28 2.72	6.0 4 1.33	2.42 .79	.23

TABLE

RESULTS AND DISCUSSION

Three particle sizes of Sul-Po-Mag were tested initially using Gage Canal water and Grangeville soil. The results obtained demonstrated that under these experimental conditions particle size had little or no effect upon the distribution of K in the soil column. Consequently, subsequent experiments with other soils and waters were carried out using only one particle size of Sul-Po-Mag, namely that designated by the producer as standard.

Reduction in CEC or fixed K. The reduction in CEC was used as the criterion to determine the amounts of K fixed. Data obtained for these soils treated with four K salts and leached with Colorado River and Gage Canal water are presented in table 2. The values reported cannot be interpreted as actual amounts of K which was fixed by the soil column in question because they represent only the analysis of a subsample (expressed in meq per 100 g of subsample) taken from the cylindrical 3 cm segment.

Values reported in table 2 for amounts of K fixed are subject, with some reservation, to an unavoidable lack of accuracy because of the methods employed. These methods involve two separate CEC determinations which are both subject to random and systematic errors. Furthermore, taking differences between these two determined quantities contributes to an overall probable error. We estimate that the values reported are accurate to ± 0.4 meg per 100 g. Amounts of K fixed with Fritted Potash as a K source are somewhat smaller and may be attributed to problems associated with obtaining representative samples. Soil samples for this treatment were taken at a later date. Although variations in the absolute values are evident, the general trends in the data presented, for all practical purposes, are identical.

Table 2 shows that vermiculitic soils (Grangeville and Cajon) fix large amounts of applied K. The source of K applied, Sul-Po-Mag, KNO₃, K₂SO₄, or Fritted Potash, apparently has little influence on amounts of K fixed as a function of depth in the soil column. Having established that the amounts of K fixed by vermiculitic soils are unaffected by the source of K applied, it necessarily follows that levels for exchangeable plus soluble K and leachability of K, under conditions where fixation capacity of the soil column exceeds the amount of K applied, will also be independent of K source. Data accumulated are in accord with this necessary condition.

The montmorillonitic soils (Visalia) in contrast to vermiculitic soils (Grangeville and Cajon) have essentially no capacity to fix.K (see table 2). Comparison of the data provides a rather dramatic expression of the effects of mineralogy on K fixation.

Grangeville and Cajon soils have a wet fixation capacity of approximately 6.5 and 3.0 meq per 100 g, respectively. This demonstrates why one cannot obtain a K fertilization response where K deficiencies occur on plants grown on these soils because normally the K application rate rarely exceeds 560 kg actual K per hectare 15 cm. Approximately 5,800 and 2,700 kg of K are required to satisfy the fixing capacity to a depth of 15 cm for the Grangeville and Cajon soils, respectively.

The data show no consistent trends that are related to the waters used for leaching. Perhaps differences would occur under long-term leaching conditions.

Although not completely conclusive, the results indicate that one must satisfy a large percentage of K-fixing capacity of each increment of soil before any appreciable K will move to lower

			Reduction	in CEC*						
Column depth	Grang	eville	Caj	on	Visa	lia				
	Colorado†	Gage†	Colorado	Gage	Colorado	Gage				
cm			meq/1	00 g						
			Sul-Po-	-Mag‡						
0-3	6.9	6.7	2.7	3.0	0.0	0.0				
6-9	7.0	6.8	3.0	2.5	0.0	0.0				
12-15	5.8	6.0	2.1	2.9	0.1	0.0				
18-21	6.5	0.0	0.0	2.6	0.0	0.6				
24-27	3.8	0.0	0.6	0.3	0.0	0.0				
30-33	1.2	0.0	0.8	0.0	0.0	0.0				
			Potassium	Nitrate‡						
0-3	7.5	6.7	2.5	0.8	0.2	0.0				
6-9	7.0	6.3	2.8	2.7	0.0	0.0				
12-15	6.4	5.7	2.2	3.1	0.1	0.1				
18-21	0.0	0.2	1.8	0.9	0.0	0.0				
24-27	0.2	0.3	1.0	0.4	0.0	0.0				
30–33	0.8	0.0	1.4	0.0	0.0	0.0				
			Potassium	Sulfate‡						
0-3	7.2	6.6	3.3	2.4	0.6	0.2				
6-9	6.9	5.7	3.5	3.0	0.0	0.5				
12-15	7.2	4.8	3.1	2.5	0.1	0.0				
18-21	4.1	0.4	2.6	1.6	0.1	0.6				
24-27	0.0	0.0	0.0	0.6	0.0	0.0				
30-33	0.1	0.1	0.2	0.0	0.0	0.4				
	Fritted Potash‡									
0-3	5.1		1.6		0.1					
6-9	5.0		1.3		0.3					
12-15	0.7		1.6		0.0					
18-21	0.8		0.2		0.0					
24-27	0.2		0.1		0.0					
30-33	0.0		0.0		0.0					

CHANGE IN CEC (FIXED K) AS A FUNCTION OF DEPTH FOR GRANGEVILLE, CAJON, AND VISALIA SOILS TREATED

TABLE 2

* The difference between CEC of the control soil columns (no K added) and K treated soil columns both expressed on

The interfere between CEC of the control soft coumins (no K added) and K freated soft coumins both expressed on an air dry weight basis.
† A total of 2.75 liters (104 surface cm) of each water was leached through the column. Fritted Potash treatment received 5.5 liters (208 surface cm) of water.
‡ 40 meq of K applied to the surface of the columns containing Grangeville and Visalia soils; 20 meq of K applied to the columns containing Cajon soil; in the case of Fritted Potash 40 meq of K was applied to all three soil series.

depths in the column. This reasoning follows from the fact that, at a particular depth in the soil column, the amount of K fixed exhibits an abrupt decrease (e.g., table 2, columns 2, 3, 4, and 5 at the 12, 18, or 24 cm depth), indicating that above this depth fixing capacity has been satisfied, but below this depth it has not. This point will be further discussed in the next section.

Exchangeable plus soluble K. Values for exchangeable plus soluble K for the soils treated with four K salts and leached with two waters are presented in table 3. In general, vermiculitic soils exchangeable plus soluble K increases with depth in the soil column and then falls off abruptly to a comparatively low level. This level is approximately equal to the level of exchangeable plus

EXCHANGEABLE PLUS SOLUBLE K CONCENTRATIONS FOR GRANGEVILLE, CAJON, AND VISALIA SOILS TREATED WITH K SALTS INDICATED AND LEACHED WITH COLORADO RIVER OR GAGE CANAL WATER

TABLE 3

	Exchangeable plus soluble K—air dry-weight basis									
Column depth	Grange	eville	Сај	on	Visa	lia				
	Colorado*	Gage*	Colorado	Gage	Colorado	Gage				
cm			meq/1	00 g						
			Sul-Po-	-Mag†						
0-3	0.39	0.56	0.21	0.25	0.31	0.37				
6-9	0.85	1.76	0.31	0.56	0.36	0.54				
12-15	0.48	1.95	0.27	0.61	0.66	0.64				
18-21	0.09	0.05	0.29	0.41	0.60	0.92				
24-27	0.08	0.06	0.15	0.16	1.09	1.44				
30-33	0.06	0.30	0.11	0.07	1.11	1.61				
			Potassium	Nitrate [†]						
0-3	0.47	3.41	0.26	0.35	0.27	0.90				
6-9	1.31	1.75	0.22	1.10	0.81	1.69				
12-15	0.81	0.37	0.48	1.08	1.14	1.21				
18-21	0.10	0.06	0.23	0.20	1.24	0.27				
24-27	0.05	0.05	0.34	0.13	1.53	1.67				
30–33	0.04	0.05	0.19	0.06	1.69	1.79				
			Potassium	Sulfate†						
0-3	0.22	1.08	0.19	0.70	0.57	1.15				
6-9	0.81	1.80	0.44	0.86	1.64	1.93				
12-15	1.64	1.59	0.85	0.80	1.23	1.73				
18-21	0.04	0.05	0.51	0.34	1.20	1.70				
24-27	0.04	0.08	0.17	0.14	1.33	1.75				
30–33	0.04	0.07	0.06	0.06	1.41	1.80				
			Fritted I	Potash†						
0-3	1.56		1.04		2.34					
6-9	1.41		0.71		1.14					
12-15	0.05		0.40		1.47					
18-21	0.05		0.06		1.35					
24-27	0.05		0.07		1.19					
30–33	0.05		0.06		1.20					

A total of 2.75 liters (104 surface cm) of each water was leached through the column. Fritted Potash treatment received

soluble K observed for the control soils. A comparison of the data presented for fixed K with that presented for exchangeable plus soluble K (table 2 with table 3) reveals that the depth in the soil column where the abrupt decrease in fixed K occurs corresponds closely to the depth at which exchangeable plus soluble K exhibits an abrupt decrease. This suggests that, for vermiculitic soils similar to those in the present study, one must first satisfy a large percentage of the fixing capacity of a depth increment of soil before the exchangeable plus soluble K content of this increment can be materially increased. If we accept that exchangeable plus soluble K is the plant-available form, as is normally the case, then from a practical point of view the results obtained indicate that massive applications of K concentrated in the soil near the root zone would be the

TABLE 4 POTASSIUM CONCENTRATIONS OF LEACHATE FROM COLUMNS CONTAINING GRANGEVILLE SOIL TREATED WITH THE K SALTS INDICATED AND LEACHED WITH COLORADO RIVER OR GAGE CANAL WATERS

					Treatment*				
Increment collected	Contr	rol	Sul-Po-	Mag	KNC	3	K₂SC	4	F. Potash
	Colorado	Gage	Colorado	Gage	Colorado	Gage	Colorado	Gage	Colorado
	_		Total concen	tration of	K per 250 m	l increme	ent (meq)		
1	0.006	0.002	0.005	0.002	0.004	0.002	0.005	0.002	0.004
2	0.005	0.002	0.014	0.007	0.015	0.011	0.007	0.008	0.004
3	0.004	0.002	0.014	0.009	0.017	0.002	0.014	0.004	0.003
4	0.003	0.002	0.010	0.004	0.007	0.002	0.007	0.005	0.004
5	0.004	0.002	0.008	0.002	0.004	0.002	0.005	0.002	0.004
6	0.004	0.002	0.005	0.002	0.004	ND†	0.004	0.002	0.004
7	0.004	0.002	0.004	0.002	0.004	ND	0.004	0.002	0.004
8	0.004	0.002	0.004	0.002	0.004	ND	0.004	0.002	0.004
9	0.004	0.002	0.004	0.002	0.003	ND	0.003	0.002	0.004
10	0.007	0.002	0.006	0.002	0.004	ND	0.005	0.002	0.003
11	0.005	0.002	0.004	0.002	0.004	ND	0.004	0.002	0.002
1 through 11‡	0.050	0.022	0.078	0.036	0.070		0.062	0.033	0.040
12 through 22¶									0.019

* Soil columns were first equilibrated with the water in question, then 40 meq of the K salts were added to the surface. No K was added to control treatment. † ND represents K content below detectable limits.

[†] ND represents K content below detectable limits. [‡] Successive increments equal to 250 ml were collected after treatments were initiated. Total volume leached through the columns was 2.75 liters or 104 surface cm.

¶ Successive increments equal to 250 ml were collected after treatments were initiated. Total volume leached through this column was 5.5 liters or 208 surface cm.

best management practice to correct K deficiencies on crops grown on these or similar soils.

In contrast to vermiculitic soils (Grangeville and Cajon) where exchangeable plus soluble K showed a maximum as a function of depth, exchangeable plus soluble K values for the montmorillonitic soil (Visalia) show a tendency toward a continual increase as a function of depth (table 3). In Visalia soil this reflects normal ion exchange behavior where salts within the water used for leaching displace K from the surface soil particles and continually move it to lower depths within the column. The high value at the surface of Visalia soil where the K sources was Fritted Potash is probably due to its limited solubility. Fritted Potash not associated with exchange may have been solubilized during the process of chemical extraction. For Grangeville and Cajon soils, K is rendered nondisplaceable and consequently does not move continually downward as leaching progresses.

Potassium concentrations of leachate collected from soil columns containing vermiculitic soils. The K concentration for each 250 ml increment collected from the soil columns after treatments were initiated are presented in tables 4 and 5. The amounts of K found in the leachate collected from columns containing Grangeville soil (table 4), the surface of which was treated with the four K salts and then leached with Colorado River or Gage Canal water, are not materially different from their corresponding control treatments. This shows that essentially all of the applied K was retained, in one form or another, by the soil in the column. One notes that the initial increments (2, 3, and 4) are generally somewhat higher in K than the succeeding increments. This observation may be real or may be an artifact caused by a small amount of applied K that moves

TABLE 5 POTASSIUM CONCENTRATIONS OF LEACHATE FROM COLUMNS CONTAINING CAJON SOIL TREATED WITH THE K SALTS INDICATED AND LEACHED WITH COLORADO RIVER OR GAGE CANAL WATER

					Treatment*				
Increment collected	Contr	ol	Sul-Po-	Mag	KNC)3	K2SC	4	F. Potash
	Colorado	Gage	Colorado	Gage	Colorado	Gage	Colorado	Gage	Colorado
			Total concen	tration of	K per 250 m	l increme	ent (meq)		
1	0.007	0.004	0.007	0.009	0.020	0.119	0.008	0.008	0.006
2	0.007	0.005	0.027	0.172	0.101	0.138	0.017	0.125	0.006
3	0.007	0.005	0.059	0.007	0.071	0.004	0.012	0.008	0.004
4	0.006	0.004	0.031	0.004	0.086	0.004	0.012	0.004	0.006
5	0.006	0.004	0.055	0.007	0.084	0.004	0.008	0.004	0.006
6	0.005	0.004	0.053	0.004	0.056	0.004	0.010	0.004	0.006
7	0.004	0.004	0.040	0.004	0.067	0.004	0.010	0.004	0.006
8	0.007	0.004	0.040	0.004	0.067	0.004	0.008	0.004	0.006
9	0.007	0.004	0.053	0.004	0.075	0.004	0.008	0.004	0.006
10	0.007	0.006	0.050	0.006	0.081	0.006	0.008	0.006	0.006
11	0.007	0.004	0.051	0.006	0.068	0.006	0.008	0.004	0.004
1 through 11 [†]	0.070	0.048	0.466	0.227	0.776	0.297	0.109	0.175	0.062
12 through 22‡									0.051

* Soil columns were first equilibrated with the water in question, then 20 meg of K salts as Sul-Po-Mag, KNO; and K₃SO₄ were added to the surface. Forty meg of K as Fritted Potash was added. No K was added to control treatment. † Successive increments equal to 250 ml were collected after treatments were initiated. Total volume leached through the columns was 2.75 liters or 104 surface cm.

‡ Successive increments equal to 250 ml were collected after treatments were initiated. Total volume leached through this column was 5.5 liters or 208 surface cm.

down the sides of the column without passing through the soil particles. Even including this possibility, the difference between the total amount of K lost by leaching (sum of all increments) for the columns containing Grangeville soil treated with all four K salts and the control Grangeville soil column is small (table 4). The range of K lost by leaching for all treatments leached with Colorado River or Gage Canal water for this soil is 0.022 to 0.078 meq. Since 40 meq of K were applied to the surface, maximum loss through leaching for this soil is less than 0.2 per cent.

Amounts of K collected in the leachates from the column containing Cajon soil are presented in table 5. The K content of increments collected from the soil columns treated with Sul-Po-Mag and KNO_3 that were leached with Colorado River water are reasonably constant after an initial 500 ml of water had passed through from similar increments for the control soil columns. Referring back to data reported for fixed K (table 2) we note that the capacity of the soil column to fix K has not been satisfied. Under these conditions, one would expect that the leachate concentrations of the K-treated soils would not depart from the controls to the extent that is observed. Two explanations are plausible. (1) Part of the surface solution has drained down the sides of the columns without passing through the soil and thus values obtained do not reflect true equilibrium between solid and solution phase. (2)The data obtained are a reflection of the relative affinity of nonfixing exchange sites for K. The first explanation seems more reasonable because K concentrations approach a maximum within the first few increments collected and it would seem that a greater volume of solution would be required for an equilibrium to be established with the nonfixing sites throughout the soil column. Even though, in the above cases, the

TABLE 6 POTASSIUM CONCENTRATIONS OF LEACHATE FROM COLUMNS CONTAINING VISALIA SOIL TREATED WITH THE K SALTS INDICATED AND LEACHED WITH COLORADO RIVER OR GAGE CANAL WATER

					Treatment*				
Increment collected	Contr	ol	Sul-Po-	Mag	KNC)3	K2SC)4	F. Potash
	Colorado	Gage	Colorado	Gage	Colorado	Gage	Colorado	Gage	Colorado
		·	Total concen	tration of	K per 250 m	l increme	ent (meq)		· · · · · · · · · · · · · · · · · · ·
1	0.074	0.049	0.192	0.334	4.156	0.601	0.908	6.015	0.049
2	0.071	0.041	3.613	3.261	7.033	9.709	7.737	1.588	0.053
3	0.065	0.041	14.706	4.476	2.327	1.432	5.179	2.625	0.046
4	0.070	0.043	3.644	13.235	2.078	1.023	2.234	3.852	0.044
5	0.069	0.041	2.174	3.069	2.110	0.908	2.046	4.000	0.041
6	0.067	0.041	2.222	1.183	2.286	0.786	2.014	3.968	0.044
7	0.049	0.041	1.646	1.156	1.726	0.831	1.455	3.906	0.064
8	0.051	0.039	1.487	1.071	1.583	0.806	1.311	1.031	0.130
9	0.047	0.036	1.359	1.255	1.359	0.716	1.199	0.938	0.298
10	0.040	0.032	0.807	1.023	1.191	0.965	1.039	0.844	0.384
11	0.038	0.034	1.023	0.919	1.047	0.863	0.911	0.734	0.598
1 through 11†	0.641	0.438	32.873	30.982	26.896	18.640	26.033	29.501	1.751
12 through 22‡									9.152

* Soil columns were first equilibrated with the water in question, then 40 meq of the K salts were added to the surface. No K was added to control treatment. † Successive increments equal to 250 ml were collected after treatments were initiated. Total volume leached through the columns was 2.75 liters or 104 surface cm.

[‡] Successive increments equal to 250 ml were collected after treatments were initiated. Total volume leached through this column was 5.5 liters or 208 surface cm.

amounts of K leached from the Ktreated columns are considerably greater than amounts leached from the control columns, total amount of K lost by leaching is less than 4 per cent of the applied.

As table 5 shows, results obtained for the columns containing Cajon soil, surface of which was treated with Sul-Po-Mag and KNO₃, then leached with Gage Canal water, and for the columns treated with K_2SO_4 leached with both Colorado River and Gage Canal water are similar to those discussed above for the Grangeville soil. Data obtained from Fritted Potash varies little from the control. Again, total amounts of K lost by leaching are small, amounting to less than 4 per cent of that applied.

Potassium concentrations of leachate collected from soil columns containing a montmorillonitic soil. Values for K concentration of leachate collected from Visalia soil columns that had K salts applied to the surface, then leached

with Colorado River and Gage Canal water, are presented in table 6. These data for non-K fixing Visalia soil are markedly different from those presented above for K-fixing Grangeville and Cajon soils (compare tables 4 and 5 with table 6). With Fritted Potash being a possible exception, under all treatments with both waters, amounts of K found in all increments collected are much greater than similar increments for the control Visalia soil. The amount of applied K lost by leaching for these soil columns ranges between 48 and 81 per cent. With the exception K₂SO₄-treated soil column, of the amount of K lost by leaching with Colorado River water is greater than that lost by leaching with Gage Canal water (table 6). This effect is, of course, due to a higher salt content of the Colorado River water which results in greater displacement of K adsorbed on the soil surfaces.

Amounts of K lost by leaching the

montmorillonitic soil (Visalia) was the only property studied which was influenced by the K source. Amounts of K lost by leaching for this soil where K sources was either Sul-Po-Mag, KNO₃, or K₂SO₄ were about 30 meq, or approximately 75 per cent of that applied. Where Fritted Potash was used as a K source under comparable conditions (i.e., where the amount of water leached through the column was 2.75 liters) only 1.75 meq of K or about 4 per cent was lost by leaching. Increasing the amount of Colorado River water used for leaching to 5.5 liters increased the amount of K lost by leaching to 10.903 meq of K, or about 27 per cent of that applied. This was still considerably less than that K lost by other sources. The inherent low solubility of the Fritted Potash was no doubt effective in decreasing the rate of K solution.

The results point out that considerable quantities of K may be lost by leaching from the profile of soils with similar characteristics. For this reason massive applications of K on soils of this type most probably are not the best management practice. Since K rather readily moves to lower depths in the soil profile, massive application of K may result in large K losses by leaching. It would seem that where K deficiences occur in similar soils, an annual small application rate (sufficient to satisfy the needs of the plant) would be the most beneficial and economical. However, the above interpretations are an extrapolation from massive applications (4 meg per 100 g) to small applications and before any actual application rate can be recommended further experiments are required.

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