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The behavior of added and native potassium of five Tennessee soils and factors affecting its availability

Jerry A. Burnette

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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 9, 1966

To the Graduate Council:

I am submitting herewith a thesis written by Jerry A. Burnette entitled "The Behavior of Added and Native Potassium of Five Tennessee Soils and Factors Affecting Its Availability." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Russell J. Lewis
Major Professor

We have read this thesis and recommend its acceptance:

W L Parks

Edward E.C. Clebsch

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate Council

THE BEHAVIOR OF ADDED AND NATIVE POTASSIUM OF FIVE TENNESSEE

SOILS AND FACTORS AFFECTING ITS AVAILABILITY

———————

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

———————

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

———————

by

Jerry A. Burnette

August 1966

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to plants. Native potassium is that potassium in the soil prior to sampling which may or may not include potassium applied by man. Experiments were conducted to study: the influence of alternate wetting and drying and of clay mineralogy on fixation and release of native and added potassium in the soil; the relation of several chemical extraction techniques to available potassium in the soil; the contributions of potassium from sand, silt and clay to the total and available potassium content of the soil; the effect of added potassium on the replacement of calcium and magnesium; the uptake of potassium by sudangrass; and the equilibria of native and added potassium in the soil by the radio-active tracer technique.

CHAPTER I

INTRODUCTION

Much research has been conducted to determine the relationships
among potassium, the soil and the plant. Although our knowledge of
these relationships has greatly increased, our understanding of the
mechanisms responsible for soil potassium release and the processes
involved in soil potassium reactions has only started. The fact that
the total potassium in a soil is not a reliable index of the capacity
of a soil to supply potassium to plants has been known for some time.
As early as 1894 (4), it was observed that part of the potassium added
as fertilizer was converted to a form not readily available to plants.

Investigations agree that the quantities of potassium removed
by chemical and biological methods cannot be absolutely categorized as
exchangeable or available potassium because the quantity removed is a
function of multiple variables.

The use of radioactive isotopes has contributed significantly
to the solutions of soil problems. They enable the distinction of
potassium added as fertilizer potassium from native soil potassium
through the technique of isotopic dilution.

The objectives for this study were to determine the behavior
of potassium added as fertilizer and native soil potassium of five
Tennessee soils and the factors affecting the availability of potassium

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CHAPTER II

REVIEW OF LITERATURE

Literature relating to the behavior of native and added potassium in the soil and factors affecting potassium fixation, release and availability is quite extensive. The potassium available to plants from a soil is generally equated with the amount of exchangeable potassium (16, 34, 44), but it is known that plants can accumulate more than this amount. If they could not, removal of potassium by crops would rapidly deplete the exchangeable potassium if no other source were present. Thus, potassium is released from difficulty available forms and thereby supplements the potassium available as exchangeable potassium (4).

The release of noxexchangeable potassium upon cropping has been correlated with the potassium released by boiling the soil for ten minutes in 1.0 N. HNO_3; a method proposed by Wood and DeTurk (50). The amounts of potassium extracted by this method and that released to the plants were correlated by Garman (16) and Grissinger, et al. (19). The release of nonexchangeable potassium to plants was correlated with the ca͏ly content of soils from Ontario, Canada (42). Doll, et al. (13) found a high correlation between the release from clay and the amount of potassium in the clay, and between the release from silt and the amount of potassium in the silt.

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The relationship between the type of minerals in the soil and the amount of potassium released on cropping has been investigated. Phillipe and White (33) obtained a correlation coefficient of .73 between the HNO_3 soluble potassium and the microcline content of the soil. Cook and Hutcheson (10) found a positive relation between the illite content in the clay and the amount of potassium released. On some British soils, the release of potassium was correlated with clay content only when the potassium content of the clay was considered (1). Reitemeier et al. (37) did not find a correlation between the release of nonexchangeable potassium and the kind of clay minerals in the soils they investigated. The relationship between release of potassium and the kind of clay mineral may be complicated because each clay mineral may have a characteristic release rate for potassium. Since release rates may vary greatly among clay minerals, it would be necessary to know the amount of each mineral present and the rate at which potassium is released from it before one could adequately describe the rate of release of difficulty available potassium in a soil.

Weathering of clay minerals causes a release of nonexchangeable potassium. Potassium becomes available through the weathering of feldspars, micas, and other potassium bearing soil minerals as well as from the clay minerals. Most soils release potassium so slowly that only a small part of the crop requirement is met by this means (4). Arnold (2) recently reviewed the weathering of potassium minerals in soils and found that feldspars are present mainly in the > 0.2 μ

fraction and are protected from rapid weathering by a coating of their decomposition products. Of the micaceous minerals, the trioctahedral forms (biotite) weather much more rapidly than the dioctahedral forms (muscovite) and as a consequence the former are rarely present in soil.

The release of potassium by dioctahedral clay is accompanied by a reduction in the charge density on the clay crystal and expansion of the clay lattice. White (49) has shown that the charge density must be reduced to 160 meq. per 100 g. for expansion to occur. Processes proposed by Jackson et al. (22) which would cause this reduction in charge are: hydroxylation of tetrahedral oxygens, oxidation of ferrous iron, dealumination of tetrahedral aluminum by replacement with silicon, and destruction of the tetrahedral layer.

Wear and White (48) compared cation fixation between clays having a high proportion of the charge arising in the tetrahedral layer and clays having a high proportion of the charge arising in the octahedral layer. Clays high in tetrahedral charge deficiency fixed more potassium than did otherwise similar clays high in octahedral charge deficiency. They found that the distance between the potassium ion and negative lattice charges to be 2.19 Å. and 4.99 Å., respectively, for the tetrahedral and octahedral layers. Since the force of attraction is inversely proportional to the square of the distance, the force of attraction of the tetrahedral charge would be more than four times as great. Beidellite, hydrous mica (illite), and vermiculite clays have relatively more tetrahedral charges than the magnesium montmorillonites

and should therefore be able to hold more potassium in a fixed condition.

Trioctahedral clays have a much higher release rate than do dioctahedral clays. Barshad (7, 8) has shown that the ease with which the ions can be replaced was related to the interlayer charge rather than to the origin of the charge.

Doll, et al. (12) found from their studies on the release of potassium from soil fractions during cropping that the potassium content of the clay and silt fractions was linearly correlated with the logarithm of the potassium uptake for each fraction. No correlation was noted between the uptake of potassium and the potassium content of the entire soil. Large amounts of potassium were removed from the coarse clay (2.0-0.2 μ), intermediate amounts from the medium clay (0.2-0.08 μ), and small amounts from the fine clay fractions (0.08 μ). This differential release of potassium by the different size clay fractions can be explained by a decrease in the activity of interlayer potassium when the potassium content of the clay is decreased.

Merwin and Peech (28) found after removing the exchangeable potassium from samples of four soils that most of the potassium released from nonexchangeable to exchangeable forms during an incubation period was derived from the clay fraction. The sand released very little potassium. The silt contributed 15-50 per cent whereas clays contributed from 40-80 per cent of the total potassium released by the soil.

Barshad (6) studied the fixation of ammonium and potassium by vermiculities and biotites that may be present in the coarse fraction as

well as in the clay fraction of soils. He found that the 100-250 μ
fraction of a Sweeney subsoil layer (30 to 32 inch layer) fixed more
ammonium than did the 1 μ fraction, notably 17.8 meq. as against 14.5
meq./100 g. Kunze and Jeffries (25) found a positive relationship be-
tween the amount of potassium fixation and the amount of clay that
collapses to 10 Å. when treated with KCl.

Potassium fixation is an important factor in potassium fertili-
zation. Fixation reduces luxury consumption and leaching; however, it
also reduces availability. The extent to which potassium fixation
occurs and the rate of its release after fixation will depend on the
soil. A knowledge of the specific reactions occurring is helpful in
planning potassium fertilization practices (4). Acid soils may fix
less potassium because the presence of nonexchangeable aluminum in the
interlayer positions will prevent collapse of the clay lattice and
reduce potassium fixation (26).

Wetting and drying will increase fixation (19, 41). Considera-
tion of the effect of drying the soil on the change in exchangeable
potassium level is of prime importance when evaluating exchangeable
potassium data. There are many values for exchangeable potassium re-
ported that have little relation to the available supply of potassium
in the soil (4). Depending upon the level of potassium in the soil,
drying may result in either fixation or release. It has been reported
by Scott et al. (39) that Ontario soils containing less than 1.1 per
cent exchangeable potassium released potassium upon drying and fixed

potassium upon drying if they contained more than this amount. Other investigators (21, 19) found the exchangeable potassium to be more highly correlated with plant uptake when the exchangeable potassium was determined on field moist samples. These same workers reported that the level of exchangeable potassium increased more on drying in soils from untreated plots than from soil where large potassium additions had been made.

Pearson (32) has reviewed the research on the influence of lime on potassium availability. He noted that liming the soil tended to decrease the availability of exchangeable potassium, increase the release of nonexchangeable potassium, increase potassium fixation and decrease the loss of potassium by leaching. Addition of lime has reduced the potassium content of the plant subsequently grown on the soil. Calcium substitutes for hydrogen and aluminum as the complementary ion and increases the potassium activity.

Volk's (46, 47) results pointed out that: long continued potassium fertilization resulted in decreasing the potassium fixing power and increasing the muscovite or muscovite-like component of the clay size fraction; and, the greater amount of potassium added, the greater was the amount fixed upon drying but the smaller was the percentage fixed. Truog and Jones (45) pointed out the relation between the amount of potassium fixed and the amount of reduction in exchange capacity of bentonite clay when the potassium saturated clay was wetted and dried or when KCl was added to a bentonite sample. Their results showed a

close correlation of the amount of potassium fixed to the amount of reduction in exchange capacity after potassium fixation, which was a strong indication that the exchangeable ions were the seat of the fixation reaction.

Page and Baver (31) studied the fixation of cations by the colloids from a Wyoming bentonite (montmorillonite) and from a Miami silt loam soil and related it to the size of the unhydrated ions. From their work, a theory was proposed that gave consideration to the ionic size of the unhydrated ions, the expanding-contracting nature of the montmorillonite type of minerals, and the geometric arrangement of the oxygen ions at the surface of the crystal layers. Their theory explained the fixation reactions of certain cations as follows: the exposed surface between the layers of the 2:1 expanding-lattice clays consists of a sheet of oxygen ions arranged hexagonally, the opening within the hexagon being 2.8 $\overset{o}{A}$. in diameter. As the clay is dehydrated, the layers contract and the ions lose their shells of oriented water molecules, approaching the unhydrated ionic diameter in size. The unhydrated ionic diameters are: Li, 1.20 $\overset{o}{A}$.; Na, 1.90 $\overset{o}{A}$.; K, 2.66 $\overset{o}{A}$.' NH_4, 2.96 $\overset{o}{A}$.; Cs, 3.38 $\overset{o}{A}$.; Mg, 1.30 $\overset{o}{A}$.; Ca, 1.98 $\overset{o}{A}$.; and Ba, 2.70 $\overset{o}{A}$. Ions with the diameter of about 2.8 $\overset{o}{A}$. are of the proper size to fit snugly into the lattice "holes" and should be held very tightly, because they are close to the negative electrical charges within the crystal, and by fitting into the "hole" they would allow the layers to come close together and be locked against rehydration and re-expansion.

Barshad (6) investigated the basal spacings of montmorillonite saturated with various cations under air-dried conditions and when subsequently immersed in water. The expansion that occurred when the magnesium, calcium, barium, hydrogen, lithium and sodium samples were wetted suggests that these ions would not be fixed. With potassium, ammonium, and rubidium, the lattice remained contracted and hence these ions would be expected to be less accessible to displacing cations.

CHAPTER III

METHODS AND PROCEDURE

Five Tennessee soils with different mineralogical properties from various regions of the state were used. The soil types were: Memphis silt loam, Maury silt loam, Hartsells loam, Baxter cherty silt loam, and Sequoia silt loam.

The Memphis soil, located in the Deep Loess region of west Tennessee is well-drained and contains a moderate amount of plant nutrients. It responds well to additions of fertilizer and occurs along level to moderately steep ridgetops and side slopes. This soil, formed in loess that is $3\frac{1}{2}$-15 feet thick, overlies sands and clays of the coastal plain. The content of organic matter in the soil is moderate and the natural fertility is high. Runoff is medium to slow, and the erosion hazard is moderate. Permeability of the surface layer and subsoil is moderate, and the available water holding capacity is high. The plow layer is generally in good tilth.

The Maury soil, located in the Outer Basin region of middle Tennessee is a deep, well-drained, brown upland soil, developed from weathered residuum of phosphatic limestone. Maury soil is highly productive, easily worked, high in phosphorus, and suited to many kinds of crops. The soil acidity and internal drainage are medium, and the moisture holding capacity is moderate.

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The Hartsells soil, located in the Cumberland Plateau region of east Tennessee is moderately deep, well-drained and developed from level-bedded, acid sandstone and sandy shale. This soil is low in natural fertility, organic matter and pH. It responds very well to fertilization, and is moderate in available moisture holding capacity. Permeability of roots and water is moderate.

The Baxter soil, located in the Highland Rim region of middle Tennessee is a well-drained, upland cherty soil derived from cherty limestone. It is medium to strongly acid, low in natural fertility, and moderate in available moisture holding capacity. It responds well to lime and fertilizer and is moderately permeable.

The Sequoia soil, located in the Southern Appalachian Valley of east Tennessee is a moderately deep, well-drained upland soil. The depth to leached or acid shale bedrock ranges from 2 to 4 feet. It is low in fertility, organic matter, and pH; but, responds well to fertilization. The surface soil is permeable and has good tilth. The subsoil is slowly permeable to moisture and the available moisture holding capacity is moderate.

Five basic studies conducted on these soils were: chemical extraction techniques for determining available potassium and total potassium in the whole soil and in the soil separates: isotopic dilution and equilibrium studies on native and added potassium using the K-42 isotope on chemically aged and fresh soils: wetting and drying the soil to simulate field conditions for extended periods of

time to determine fixation and/or release: plant uptake studies

of potassium with sudangrass: determinations of calcium and mag-

nesium displaced from the soil after adding different amounts of potas-

sium.

Soil samples were collected from the Ap or A$_2$ horizon and allowed

to air dry in the greenhouse before being passed through a 10 mesh sieve.

The potassium treatments were 100, 200 and 400 lbs. of potassium per

acre applied as KCl. A 1:6 soil to water ratio was used for all

the potassium extractions. All five soils were used in each experiment

and were replicated three times except in the aging and chemical

extraction experiments, which were replicated twice.

For the chemical extraction technique experiments, ten gram

samples of each air dry soil were treated with one extractant per

sample of 1.0 N. $NH_4C_2H_3O_2$, 0.05 N. H_2SO_4 + 1 per cent $(NH_4)_2SO_4$, and

1.0 N. NH_4Cl for potassium extraction by the Shaw and Veal (40) method;

nitric acid extraction with 1.0 N. boiling HNO_3 was made according to

the procedure described by Pratt and Morse (35); and total decomposi-

tion of the whole soil sample by HF and $HClO_4$ acids was performed by

the procedure of Jackson (23).

The procedure for extracting potassium with 0.1 N. naphthyl-

amine-HCl was that used by Ellis:[*]

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[*]B. G. Ellis, Michigan State University, East Lansing, Michigan.
Private communication with R. J. Lewis, The University of Tennessee,
Knoxville, Tennessee.

1.   Duplicates of 5-gram samples of soil were placed in 100-ml. centrifuge tubes.

2.   Fifty ml. of 0.1 N-naphthylamine-HCl solution were added to the soil and shaken for 24 hours.

3.   The soil and solution were centrifuged for 15 minutes at 2,400 r.p.m.

4.   The clear supernatant liquid was decanted and analyzed for potassium.

5.   The above was repeated five times on the same soil sample and an accumulative curve was made for the amount of potassium removed.

The procedure for the isotopic equilibrium experiments was as follows:

1.   A standard solution of radioactive K-42 (half life 12.47 hrs.) was prepared and added to the potassium treated soils.

2.   The isotope was shaken with the soil for 30 min. and centrifuged for 15 min. at 3000 r.p.m.

3.   Three ml. of the supernatant liquid were withdrawn and counted for gamma emission for one minute on a scintillation counter.

4.   After the K-42 decayed, potassium in the supernatant solution was determined by flame photometry.

5.   Corrections were made on the recorded radioactivity for background activity, geometry and radioactive decay.

6. Calculations were made to determine the isotopic exchangeable potassium of the soil by using the following isotopic dilution formula:

$$K \text{ traced} = K \text{ added} \left(\frac{\text{specific activity added}}{\text{specific activity remaining}} - 1 \right) .$$

The procedure used for potassium uptake studies with sudangrass was as follows:

1. Thirty seedlings were grown on fiberglass screen in nutrient solution for 4 weeks. The nutrient solution was changed once a week and potassium reduced each week as following: 26, 24, 8.9 and 0.0 mg. potassium per 600 ml. respectively.

2. Radioactive potassium was added to 40 g. of the five soils treated with different levels of potassium. The plant roots were then placed into the radioactive soil-paste for a 12 hour period.

3. Plants were harvested just above the roots, weighed and 3-g. portions packed into plastic counting tubes for radioactive assay.

4. The remainder of the plant tissue was dried in a forced air oven at 70°C. and digested by a modification of the wet oxidation procedure of Gieseking, et al. (18) for potassium determination.

5. The soil-paste was dried and analyzed for isotopic and $NH_4C_2H_3O_2$ exchangeable potassium.

6. Radioactive potassium taken up by the plants was determined by the isotopic dilution method.

7. For the greenhouse experiment, thirty seeds were planted, 57 mg. of nitrogen, 37 mg. of phosphorus, and the potassium treatments were added to 1000 g. of soil.

The following procedure was used for aging the soil 10 months:

1. Five grams of each soil sample were weighed into 25 ml. Pyrex beakers and treated with different levels of potassium.

2. Each sample was wetted to field capacity with distilled water and covered with a watch glass in a position to permit air drying at room temperature.

3. The wetting and drying cycle was repeated at approximately weekly intervals for 10 months.

4. After aging, the soils were analyzed for water soluble and isotopic exchangeable potassium.

5. The amount of potassium fixed against isotopic exchange after aging was calculated by adding the amount of potassium traced on the fresh soil minus the potassium traced on the aged soils to the amount of potassium in the water extract solution of the fresh soil minus the potassium in the water extract of the aged soil.

The following procedure was used for aging the soils 3 months and determining the displaced calcium and magnesium.

1. Five-gram samples were weighed into 5 oz., plastic, narrow mouth bottles, treated with different levels of potassium and covered with aluminum foil.

2. The wetting and drying method was the same as the preceding procedure except for the aging period.

3. The soils were extracted with distilled water and analyzed for hydrogen, potassium, magnesium, calcium and chlorine.

4. Calcium and magnesium were determined with the Perkin-Elmer 303 Atomic Absorption Spectrophotometer.

5. Hydrogen ion concentration was determined by both the titration indicator method and the Beckman Expandomatic pH meter.

6. Chlorine was determined colorimetrically by the method of Bergman and Sanik (9).

CHAPTER IV

RESULTS

I. CHEMICAL EXTRACTION TECHNIQUES

Table 1 shows the amount of potassium released with different chemical extractants and the total soil potassium. Total digestion of the soil with HF and $HClO_4$ acids extracted the largest quantity of potassium and distilled water extracted the least. Between these extremes, boiling 1.0 N. HNO_3 and 0.1 N. naphthylamine-HCl were more severe extractants of potassium than were 1.0 N. $NH_4C_2H_3O_2$, 1.0 N. NH_4Cl, and 0.05 N. H_2SO_4 + 1 per cent $(NH_4)_2SO_4$.

Linear correlation coefficients were calculated for the relationships between the amount of potassium extracted by a chemical method and that extracted by sudangrass grown for three weeks on five untreated soils. Correlation coefficients for potassium extracted by sudangrass (mg./g.) and by 1 N. $NH_4C_2H_3O_2$, 0.1 N. naphthylamine-HCl, 1 N. HNO_3, 48 per cent HF + conc. $HClO_4$, and distilled water were: r = .85, r = .50, r = .48, and r = .30, and r = .25, respectively. The correlation coefficient of r = .85 for potassium extracted by 1.0 N. NH_4Ac and that extracted by sudangrass was significant at the .01 level of probability. Correlation coefficients of r = .50, r = .48, r = .30 and r = .25 were not significant at the .05 level of probability. By omitting the Maury soil, a significant correlation coefficient of r = .81 was obtained for potassium removed by sudangrass and water soluble

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TABLE 1. Release of potassium from five soils using different chemical extraction techniques.

Chemical Extractant	Memphis	Maury	Hartsells	Baxter	Sequoia
			Meq./100 g.		
Samples collected in 1956 except Memphis					
48% HF + conc. $HClO_4$	38.50	32.35	20.20	21.70	19.30
Boiling 1.0 N. HNO_3	0.63	1.05	0.27	0.11	0.81
0.1 N. 1-Naphthylamine Hcl	0.37	0.82	0.35	0.32	0.63
1.0 N. NH_4Cl	0.18	0.43	0.10	0.07	0.25
1.0 N. $HN_4C_2H_3O_2$	0.20	0.37	0.07	0.09	0.28
Samples collected in 1965					
1.0 N. $NH_4C_2H_3O_2$	0.20	0.63	0.40	0.11	0.36
0.05 N. H_2SO_4 + 1% $(NH_4)_2SO_4$	0.21	0.61	0.37	0.10	0.32
Distilled water	0.05	0.04	0.11	0.03	0.06

potassium of the four remaining soils.

II. TOTAL POTASSIUM CONTENT OF SOILS AND SOIL FRACTIONS

The total potassium content of soils and soil fractions is listed
in Table 2. The content of potassium in the whole soil samples ranged
from 0.73 to 1.47 per cent. The content of potassium in the soil frac-
tions ranged from 0.07 to 0.79 per cent for sand, 0.39 to 1.57 per
cent for silt, and 0.90 to 1.89 per cent for clay.

Of the sand, silt and clay fractions, the clay contained the
largest amount of potassium in Maury, Harsells and Sequoia soils and
the silt contained the largest amount of potassium in Memphis and Baxter
soils. The least quantity of potassium was found in the sand fraction
of all soils except Sequoia in which the silt fraction contained the
least potassium.

The distribution of potassium among the three fractions was
calculated. The silt fraction supplied a larger part of the total soil
potassium than did the sand or clay in all soils except Sequoia which
had the largest quantity of its potassium supplied by the clay. All
the soils contained over 60 per cent silt except for Hartsells which
contained 44.7. The clay content of the soils was below 20 per cent
except for Sequoia and Maury; and the largest quantity of potassium for
any soil fraction was in the Sequoia clay which was almost 2 per cent
potassium. The sand fraction contributed less potassium to the total
soil potassium than any other fraction for all soils.

TABLE 2. Mechanical analysis of soils and content of total potassium of whole soils and of soil fractions.

Soil Series	Memphis			Maury			Soil Fractions Hartsells			Baxter			Sequoia		
	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay
							------Per Cent------								
Mechanical analysis	10.6	79.3	10.0	15.3	60.6	24.0	41.4	44.7	14.0	9.4	70.2	12.5	7.6	72.0	20.4
K content in soil fraction	0.62	1.57	1.31	0.70	1.30	1.77	0.07	0.97	1.07	0.21	0.91	0.90	0.79	0.39	1.89
Per cent of total K in each fraction	4.60	86.30	9.09	8.07	59.62	32.30	4.99	70.58	24.43	2.35	84.39	13.25	8.21	38.99	52.79
Quantity of soil K that comes from each fraction	0.07	1.25	0.13	0.11	0.79	0.42	0.03	0.43	0.15	0.02	0.71	0.12	0.06	0.28	0.38
					-----Whole Soil (Per Cent)-----										
Summation of K in all fractions		1.45			1.32			0.61			0.84			0.72	
Total soil K (whole soil analysis)		1.47			1.23			0.76			0.83			0.73	

III. DATA ON SOIL AGING

Data in Tables 3, 4 and 5 show the effect of aging on water
soluble and on isotopic equilibria of added and original potassium.
According to these data fixation and release of potassium occurred in
some soils due to aging.

With the high levels of added potassium, significantly more
potassium was retained on the soil against water extraction for the
aged soil than for the fresh soils; however, for the low and medium
levels of added potassium on the Memphis and Maury soils, potassium was
released after aging. The amount of added and original potassium that
was retained against water extraction due to aging was greater for all
levels of added K in Hartsells and Sequoia than in the other soils.
Potassium was retained due to aging for all levels of added potassium
on the Baxter; however, Maury and Memphis retained more added potassium
due to aging at high levels of added potassium than did Baxter.

On the aged soils traced with K^{42}, it was found that aging in-
hibited isotopic exchange for all soils and for all treatment levels
with a portion of the original and added potassium in the soil. The
order from greatest to least amounts of potassium fixed against iso-
topic exchange are: for zero potassium level, Hartsells, Maury, Sequoia,
Memphis and Baxter; for the high potassium level, Hartsells, Maury,
Memphis, Sequoia and Baxter. The ranges of proportions of added
potassium retained on the soil against water extraction after aging
for all levels of added potassium are: low level--0 to 73.4 per cent;

TABLE 3. Effects of aging on water soluble and isotopic exchange of added K^{42}, fertilizer and original potassium in the soil.

| Soil Series | K Added | Fresh Soil | | Aged Soils | | |
| | | | | 10 Months | | 3 Months |
		Water Soluble	K^{42} Traced	Water Soluble	K^{42} Traced	Water Soluble
		---------------------Meq./100 g.---------------------				
Memphis	0.000	0.040	0.272	0.046	0.121	0.046
	0.128	0.060	0.338	0.061	0.230	0.084
	0.256	0.123	0.446	0.123	0.370	0.092
	0.512	0.264	0.731	0.169	0.486	0.214
Maury	0.000	0.046	0.735	0.061	0.414	0.075
	0.128	0.072	0.822	0.084	0.506	0.082
	0.256	0.092	0.876	0.107	0.573	0.092
	0.512	0.167	1.154	0.138	0.785	0.199
Hartsells	0.000	0.097	0.386	0.031	0.092	0.123
	0.128	0.155	0.491	0.061	0.184	0.153
	0.256	0.230	0.611	0.123	0.343	0.214
	0.512	0.395	0.870	0.261	0.577	0.314
Baxter	0.000	0.032	0.160	0.031	0.043	0.846
	0.128	0.081	0.261	0.078	0.221	0.069
	0.256	0.141	0.358	0.130	0.331	0.115
	0.512	0.313	0.549	0.261	0.548	0.161
Sequoia	0.000	0.074	0.289	0.046	0.159	0.084
	0.128	0.121	0.369	0.084	0.253	0.138
	0.256	0.184	0.516	0.123	0.419	0.199
	0.512	0.343	0.636	0.199	0.594	0.153

TABLE 4. Effects of aging for 10 months on fixation and retention of added and original potassium against distilled water extraction and isotopic exchange.

Soil Series	K Added	K-Retained Against Water Extraction			K-Fixed Against Isotopic Exchange		
		Soils		Retained Due to	Soils		Fixed Due to
		Fresh	Aged	Aging	Fresh	Aged	Aging
				Meq./100 g.			
Memphis	0.000		-0.006	-0.006	0.272	0.121	0.145
	0.128	0.108	0.107	-0.001	0.338	0.230	0.107
	0.256	0.173	0.173	0.000	0.446	0.370	0.076
	0.512	0.288	0.383	0.095	0.731	0.486	0.340
Maury	0.000		-0.015	-0.015	0.735	0.414	0.306
	0.128	0.102	0.090	-0.012	0.822	0.506	0.304
	0.256	0.220	0.205	-0.015	0.876	0.573	0.288
	0.512	0.391	0.420	0.029	1.154	0.785	0.398
Hartsells	0.000		0.066	0.066	0.386	0.092	0.360
	0.128	0.070	0.164	0.094	0.491	0.184	0.401
	0.256	0.123	0.230	0.107	0.611	0.343	0.375
	0.512	0.214	0.348	0.134	0.870	0.577	0.427
Baxter	0.000		0.001	0.001	0.160	0.043	0.116
	0.128	0.079	0.087	0.008	0.261	0.221	0.037
	0.256	0.147	0.158	0.011	0.358	0.331	0.038
	0.512	0.231	0.283	0.052	0.549	0.548	0.052
Sequoia	0.000		0.028	0.028	0.289	0.159	0.158
	0.128	0.081	0.118	0.037	0.369	0.253	0.153
	0.256	0.146	0.207	0.061	0.516	0.419	0.158
	0.512	0.243	0.387	0.144	0.636	0.594	0.186

TABLE 5. The portion of added potassium tagged with K^{42} that was retained on the soil and that was retained due to aging.

Soil Series	K Added	Added K Retained	Added K Retained Due to Aging
	Meq./100 g.	Per Cent	Per Cent
Memphis	0.128	15.8	-0.8
	0.256	8.4	0.0
	0.512	4.6	18.6
Maury	0.128	44.5	-9.3
	0.256	41.7	-5.8
	0.512	32.7	5.6
Hartsells	0.128	25.3	73.4
	0.256	20.2	41.8
	0.512	14.3	26.2
Baxter	0.128	6.0	6.2
	0.256	3.6	4.3
	0.512	1.0	1.0
Sequoia	0.128	32.7	28.9
	0.256	31.7	23.8
	0.512	29.2	28.1

medium level--0 to 41.8 per cent; high level 0 to 26.2 per cent.

IV. DISPLACEMENT OF CALCIUM AND MAGNESIUM WITH POTASSIUM

Table 6 shows the amount of calcium and magnesium displaced from each soil by three levels of added potassium. For all soils and all treatments except for the low and medium treatments of Baxter, the amount of calcium and magnesium displaced increased as potassium was added. The potassium retained on the soil increased significantly with greater potassium applications. As is shown by Figure 1, aging for three months caused a higher percentage of the potassium retained on the soil of added potassium except for potassium treatments of the Baxter soil and the high level of potassium on the Sequoia.
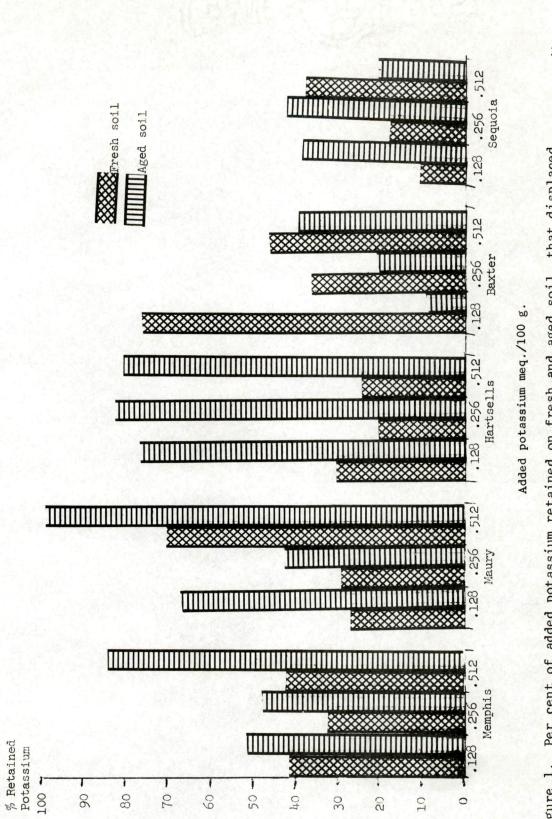
Ninety-nine and two tenths per cent of the retained potassium displaced calcium and magnesium for the high level of added potassium on the aged Maury soil. For all three levels of added potassium, combined a larger portion of calcium and magnesium was displaced by the retained potassium from the aged Hartsells soil than from any of the other soils. The lowest quantity of retained potassium that displaced calcium and magnesium was 8.2 per cent for the low level of added potassium on the aged Baxter soil.

V. ISOTOPIC EXCHANGE AS A FUNCTION OF TIME

Table 7 shows the effects of elapsed time between adding the potassium treatments and K^{42} isotope on soil potassium equilibria. From the data of Table 7, it appears that more soil potassium was traced by K^{42}

TABLE 6. Amounts of magnesium and calcium displaced and potassium retained on fresh and aged soils treated with three levels of potassium

K Added Meq./100 g.	Memphis		Maury		Hartsells		Baxter		Sequoia	
	Fresh	Aged	Fresh	Aged	Fresh	Aged	Fresh	Aged	Fresh	Aged
	µeq./100 g.									
Mg Displaced										
0.128	9.4	14.8	0.0	17.8	8.4	69.6	17.9	2.6	9.5	17.2
0.256	21.8	24.8	2.5	22.8	11.9	74.6	23.4	10.0	21.9	22.2
0.512	33.2	47.0	9.0	55.0	14.3	74.6	43.7	34.8	53.6	38.4
Ca Displaced										
0.128	27.0	30.0	27.0	60.0	12.0	30.0	33.0	6.0	0.0	11.0
0.256	30.0	75.0	60.0	75.0	15.0	60.0	27.0	27.0	9.0	36.0
0.512	102.0	240.0	294.0	33.0	72.0	180.0	81.0	117.0	60.0	48.0
Mg + Ca Displaced										
0.128	36.4	44.8	27.0	77.8	20.4	99.6	50.9	8.6	9.5	28.2
0.256	51.8	99.8	62.8	97.8	26.9	134.6	50.4	37.0	30.9	58.2
0.512	135.2	287.0	303.0	385.0	86.3	254.6	124.7	151.8	113.6	87.4
K Retained										
0.128	92.7	89.6	111.1	121.2	72.7	128.0	68.2	105.0	89.7	74.0
0.256	167.0	210.0	239.1	239.0	142.1	164.8	142.5	187.0	188.5	141.4
0.512	323.2	344.0	435.2	388.0	266.5	320.8	277.5	397.0	312.6	443.4
K Retained that Displaced Ca + Mg (Per Cent)										
0.128	39.3	50.0	24.3	64.2	28.1	77.8	74.6	8.2	10.6	38.1
0.256	31.0	47.5	26.3	40.9	18.9	81.7	35.4	19.8	16.4	41.1
0.512	41.8	83.4	69.6	99.2	23.8	79.4	44.9	38.2	36.3	19.7

Figure 1. Per cent of added potassium retained on fresh and aged soil, that displaced calcium and magnesium.

TABLE 7. Effect of elapsed time between adding KCl treatments and K^{42} isotope on soil potassium equilibria.

| Soil Series | K Added | 1 Hour | | 12 Hours | | 24 Hours | |
		Water Soluble	K^{42} Traced	Water Soluble	K^{42} Traced	Water Soluble	K^{42} Traced
		------------------------------Meq./100 g.----------------------					
Memphis	0.000	0.040	0.272	0.046	0.295	0.046	0.267
	0.128	0.077	0.338	0.083	0.375	0.081	0.349
	0.256	0.123	0.446	0.133	0.499	0.140	0.475
	0.512	0.264	0.731	0.261	0.728	0.264	0.509
Maury	0.000	0.046	0.735	0.060	0.962	0.049	0.726
	0.128	0.072	0.822	0.069	0.861	0.063	0.753
	0.256	0.092	0.876	0.095	0.977	0.094	0.887
	0.512	0.167	1.154	0.144	1.132	0.155	1.088
Hartsells	0.000	0.094	0.386	0.109	0.409	0.104	0.462
	0.128	0.155	0.491	0.181	0.555	0.169	0.520
	0.256	0.230	0.611	0.172	0.474	0.247	0.640
	0.512	0.395	0.870	0.390	0.909	0.394	0.866
Baxter	0.000	0.032	0.160	0.035	0.168	0.027	0.112
	0.128	0.081	0.261	0.089	0.297	0.078	0.201
	0.256	0.141	0.358	0.143	0.290	0.143	0.326
	0.512	0.313	0.549	0.313	0.561	0.293	0.496
Sequoia	0.000	0.074	0.289	0.094	0.346	0.080	0.295
	0.128	0.121	0.369	0.133	0.385	0.127	0.381
	0.256	0.184	0.516	0.199	0.472	0.216	0.628
	0.512	0.343	0.636	0.322	0.592	0.313	0.795

when the K^{42} was added to the soil 12 hours after the potassium treat-
ments than when it was added either 1 or 24 hours after the potassium
treatments. Table 8 shows the effect of shaking time on the K^{42} traced
potassium. From these data, it appears that more potassium was traced
on the soil by K^{42} when the soil and solution were shaken together for
12 hours.

VI. SHORT TIME POTASSIUM UPTAKE BY SUDANGRASS

Table 9 shows the potassium content and yields of sudangrass
grown on potassium treated soils for three weeks. There were no simple
trends of potassium content and yield of sudangrass with the different
levels of added potassium; however, the LSD test indicated a significant
difference at the .05 level of probability among soils for yield and
potassium content of the plants. For the zero level of potassium, the
yields in grams of sudangrass for each soil were: Memphis--0.942,
Maury--0.853, Baxter--0.837, Sequoia--0.708, and Hartsells--0.464 and
for the per cent potassium content in plants were. The potassium con-
tents of plants growing in soils receiving no potassium fertilizer were:
Maury--3.9, Hartsells--3.7, Memphis--3.3, Sequoia--3.2 and Baxter--3.0
per cent respectively.

The data for K^{42} uptake by sudangrass after contact with the
soil system for 12 hours are shown in Table 10. Statistical analysis by
the LSD test indicated that there were no significant difference at the
.05 level of probability among the potassium content in the plants grown
on the soils treated with different amounts of potassium. There was a

TABLE 8. Effect of shaking time on the equilibria of added and orig-
inal potassium in the soil.

Soil Series	K Added	Water Soluble			K^{42} Traced		
		0.5 hr.	12 hrs.	24 hrs.	0.5 hr.	12 hrs.	24 hrs.
		---------------------------------Meq./100 g.--------------------					
Memphis	0.000	0.156	0.210	0.229	0.673	0.690	0.650
	0.128	0.198	0.236	0.278	0.752	0.734	0.698
	0.256	0.235	0.318	0.302	0.818	0.910	0.706
	0.512	0.347	0.396	0.423	1.017	0.982	0.885
Maury	0.000	0.055	0.077	0.072	0.419	0.565	0.417
	0.128	0.064	0.080	0.081	0.366	0.491	0.404
	0.256	0.104	0.095	0.110	0.465	0.460	0.424
	0.512	0.195	0.170	0.195	0.690	0.639	0.693
Hartsells	0.000	0.046	0.052	0.409	0.095	0.095	0.082
	0.128	0.106	0.113	0.123	0.164	0.171	0.240
	0.256	0.186	0.196	0.156	0.248	0.268	0.189
	0.512	0.377	0.370	0.307	0.447	0.437	0.332
Baxter	0.000	0.041	0.046	0.046	0.061	0.069	0.056
	0.128	0.104	0.110	0.118	0.136	0.151	0.141
	0.256	0.184	0.184	0.186	0.217	0.212	0.220
	0.512	0.368	0.365	0.322	0.381	0.401	0.391
Sequoia	0.000	0.107	0.098	0.083	0.241	0.235	0.217
	0.128	0.124	0.126	0.118	0.235	0.261	0.243
	0.256	0.184	0.153	0.172	0.325	0.286	0.355
	0.512	0.314	0.319	0.307	0.460	0.506	0.419

TABLE 9. Effect of levels of soil potassium on yield and potassium content of sudangrass grown on 1000 grams of five soils in the greenhouse for three weeks.

Soil Series	K Added	K Content of Plants		Total Dry Weight
	Mg.	Mg./g.	Total Mg.	Grams
Memphis	0	33.3	28.3	0.942
	100	37.8	40.3	1.149
	200	40.6	37.1	0.972
	400	41.9	42.2	1.072
Maury	0	38.6	30.5	0.853
	100	39.5	29.0	0.781
	200	40.5	29.8	0.782
	400	40.4	29.9	0.811
Hartsells	0	36.9	17.8	0.464
	100	36.9	18.2	0.522
	200	34.3	16.8	0.491
	400	33.8	16.0	0.501
Baxter	0	29.6	23.4	0.837
	100	36.3	32.0	0.939
	200	36.0	27.0	0.806
	400	37.1	32.4	0.905
Sequoia	0	31.6	21.6	0.708
	100	33.7	26.2	0.800
	200	27.8	12.1	0.470
	400	30.9	13.0	0.641

TABLE 10. Potassium content, yield and K^{42} uptake of sudangrass
seedlings grown in nutrient solution and transferred to
potassium treated soils for 12 hours.

	K Added	Yield Dry Weight	K-Content in Plant	K in Plant	K^{42} Removed by Plants
	Mg./40 g.	Grams	Mg.	Per Cent	Per Cent
Memphis	1.0	1.018	31.4	3.14	13.0
	3.0	1.348	32.6	2.46	19.2
	5.0	1.301	34.7	2.69	18.9
	9.0	1.230	32.6	2.67	16.7
Maury	1.0	1.387	34.1	2.46	3.4
	3.0	1.104	30.7	2.88	8.0
	5.0	1.667	31.4	2.79	6.3
	9.0	1.200	31.0	2.67	8.5
Hartsells	1.0	1.311	34.6	2.64	7.8
	2.0	1.132	28.4	2.55	5.2
	5.0	1.041	26.3	2.65	4.9
	9.0	1.084	29.4	3.04	11.1
Baxter	1.0	1.194	35.2	3.00	12.2
	3.0	1.400	32.4	2.45	16.3
	5.0	1.337	31.3	2.37	22.4
	9.0	1.244	30.1	2.39	19.6
Sequoia	1.0	1.271	31.3	2.50	21.9
	3.0	1.126	29.8	2.65	11.8
	5.0	1.241	27.6	2.21	9.8
	9.0	1.248	32.1	2.61	13.9
Control	0.0	1.109	33.6	3.03	
	0.0	1.314	35.1	2.67	

significant difference at the .05 level of probability for K^{42} removed

by the plants on some soils. From the uptake data Memphis had signifi-

cantly more K^{42} removed by the plants than did any ot the other soils.

There was no significant difference between Baxter and Sequoia, or be-

tween Maury and Hartsells; however, Maury and Hartsells had signifi-

cantly less K^{42} removed by plants than did any of the other soils. The

data on potassium uptake by sudangrass in Table 10 indicated that the

control plants which were not in contact with the soil contained as much

potassium as the plants that had been in contact for 12 hours with the

fertilizer potassium treated soils. Therefore no fertilizer potassium

could be detected as being removed from the soil.

VII.   POTASSIUM RELEASE VS. CLAY MINERALOGY AND POTASSIUM
CONTENT OF WHOLE SOIL AND SOIL FRACTIONS

The relationships of extracted potassium content of the silt

fraction and total soil and the illite content of the soil are shown

in Table 11. The relationships of the clay content of the soil,

potassium content of the clay and potassium released by several

chemical extractants are shown in Table 12. The per cent potassium

in the silt fraction and the total potassium content of the soils were

related to each other and to the illite and quartz content of the clay.

Potassium released by all soils to 0.1 N. naphthylamine-HCl, boiling

1.0 N. HNO_3, and to 1.0 N. $NH_4C_2H_3O_2$ was related to the potassium

content of the clay, the clay content of the soil, and to the potas-

sium in the soil that comes from the clay.

TABLE 11. <u>Relationships</u> <u>of</u> <u>illite</u> <u>content</u>, <u>potassium</u> <u>content</u> <u>in</u> <u>the</u> <u>silt</u> <u>fractions</u>, <u>potassium</u> <u>content</u> <u>in</u> <u>the</u> <u>total</u> <u>soil</u> <u>and</u> <u>clay</u> <u>mineralogy</u>.

Soil Series	Illite Content	K-Content in Silt	Total K	Clay Mineralogy*
		-------Per Cent-------		
Memphis	10-40	1.57	1.47	$M_2I_2K_2Q_3$
Maury	10-40	1.30	1.23	V_2 $V/M_2K_2I_2Q_3$
Baxter	10-40	0.91	0.83	$V_2K_2I_2Q_2$
Hartsells	10	0.97	0.76	$V_1K_2I_2Q_3$
Sequoia	--	0.39	0.73	$V_2K_2M_2Q_2$

*Clay mineralogy analysis was performed by C. I. Rich, Agronomy Department, Virginia Polytechnic Institute in 1956.

TABLE 12. Comparisons of potassium released by several chemical
extractants with per cent clay in the soil, per cent
potassium in the clay, and potassium in the soil that
comes from the clay.

Soil Series	Clay in Soil	K-Content in Clay	K in Soil from the Clay	HNO_3	$NH_4C_2H_2O_2$	1-Naphthylamine-HCl
	-----Per Cent------------			-----------Meq./100 g.-------------		
Maury	24.0	1.77	10.87	1.05	0.37	0.82
Sequoia	20.4	1.89	9.87	0.81	0.28	0.63
Memphis	10.0	1.31	3.35	0.63	0.20	0.37
Hartsells	14.0	1.07	3.86	0.27	0.07	0.35
Baxter	12.5	0.90	3.20	0.11	0.09	0.32

CHAPTER V

DISCUSSION AND CONCLUSION

I. SOIL POTASSIUM RELEASE

It was concluded that soils which retained or fixed large amounts
of added potassium would also have larger amounts of potassium readily
available than soils that retained or fixed less potassium. This is in
agreement with the findings of Barber and Humbert (4) that fixed potas-
sium is usually more readily released than native potassium. There was
a close relationship among the results of the following tests: potas-
sium released by boiling 1.0 N..HNO$_3$; potassium retained on the soil
after aging with the high level of added potassium; quantity of added
potassium at all levels that was retained on the fresh soil; and the
quantity of potassium in the clay fraction. It was concluded that
predictions can be made from the results on the preceding tests as to
the potassium supplying power and available potassium of the five
soils.

Assuming similar environmental and fertilization conditions, the
five soils were ranked for their ability to supply potassium to plants
in the following order: Maury, Sequoia, Memphis, Hartsells, and Baxter.
There was no significant relation between the total potassium and avail-
able potassium of the five soils.

Cropping the five soils for three weeks with sudangrass revealed
no significant difference of potassium uptake among the potassium

There did exist a significant correlation coefficient of .85
between the amounts of potassium released from the soil to the plants
and the amounts of potassium released from the soil to the 1.0 N.
$NH_4C_2H_3O_2$ extracted which is in agreement with the findings of Garman
(16), Pratt (35) and Sutton and Seay (44). It was concluded from this
correlation that most of the potassium removed by the plants for the
first few weeks of cropping came from the exchangeable form and that
crops with a high demand for potassium in their first few weeks of growth
should be grown on soils high in exchangeable potassium.

The exchangeable potassium is not a good indication of the avail-
able potassium over an entire growing season because the exchangeable
potassium is soon depleted and the amount of available potassium
depends upon the rate of release of the nonexchangeable potassium which
has a slower release rate than the water soluble and exchangeable potas-
sium. Among other factors, differences in cropping history, seasonal
variation and degree and period of dryness might cotribute to the noted
variation in the $NH_4C_2H_3O_2$ extracted potassium for the same soils
between the 1956 and 1965 sample collection dates. The Maury and
Hartsells samples were taken from cropland and probably received some
potassium fertilization during the decade between sampling dates.

It was concluded that the potassium content of the silt and total
soil can be predicted by the illite content of the clay as is shown in
Table 11, page 35. Memphis appeared to have a higher illite content
than the other soils and contained the largest quantity of potassium
in the silt and total soil, while Sequoia had practically no illite and

the least amount of potassium in the silt and total soil. No relation-
ships were observed between the illite content of the clay and the potas-
sium released from the soil as was found by Cook and Hutcheson (10).

From all soils sampled in 1956, and Memphis, the potassium re-
leased to 0.1 N. naphthylamine-HCl, boiling in HNO_3, and 1 N. $NH_4C_2H_3O_2$
was related to the potassium content of the clay fraction and the clay
content of the soil. This was in agreement with the work of Arnold (1)
and Doll et al. (12). When comparing the clay content of the soil to
potassium released from the soil, the Memphis soil did not follow the
same trend that the other soils followed. Although Memphis contained a
smaller amount of clay than Hartsells and Baxter, its clay contained a
greater quantity of potassium and the amounts released by chemical extrac-
tion were greater. This greater release of potassium in Memphis than
Hartsells and Baxter is due to the greater potassium content of the clay
and silt fractions of Memphis than of the clay and silt fractions of
Hartsells and Baxter. From Table 11, page 35, it can be seen that the
potassium in the Memphis soil that comes from the silt was almost twice
as great as that in the Baxter silt and three times as great as that in
the Hartsells. The Baxter and Memphis contained about the same amount
of silt which was about twice the silt content of the Hartsells. It has
been reported from mineralogical analyses (4) that the silt fraction con-
tained as much of the clay type minerals as did the clay size fraction.
It would be more practical to draw conclusions for soil potassium
behavior in relation to types and amounts of minerals if more precise

data were available on the quantity and type of minerals in each size fraction.

II. FIXATION AND RETENTION OF ADDED AND ORIGINAL POTASSIUM

The amount of potassium retained on the soil was closely related with its clay content and clay mineralogy. The soils in order from greatest to least quantities of added potassium retained were: Maury, Sequoia, Hartsells, Memphis and Baxter. The results of added potassium retained on the soils were in agreement with the findings of Volk (48). His findings were that potassium retention increased with potassium additions but the percentage of potassium retained decreased.

On all fresh soil samples, potassium was retained against distilled water extraction for every level of added potassium and the amount of added potassium that was retained was significantly different among the levels of added potassium and soil types. The soils responded differently in retaining potassium after aging than they did while fresh. Potassium was retained for all levels of added potassium on the aged soils; but, for the low levels of added potassium on Memphis and Maury, there was less retained after aging than was retained on the fresh soils. From this behavior, it was assumed that release was occurring in these soils at a greater rate than fixation under the aging conditions. The potassium fixed against water extraction by aging was closely related to the quantity of clay in the soil and the potassium released by 0.1 N. naphthylamine-HCl and boiling 1.0 N. HNO_3.

The quantity of added potassium retained due to aging was associated with the ratio of vermiculite to illite in the soil clay. Hartsells and Sequoia contained the largest vermiculite to illite ratios and had the largest quantity of added potassium retained due to aging. This may be partially explained by the fact that vermiculite had a larger amount of exchange sites (CEC) than illite and that the vermiculite of Hartsells and Sequoia contained more of the high charge trioctahedral layers, which were easier collapsed after aging with added potassium, than did the other soils. Memphis, Maury and Baxter contained a larger quantity of illite in the clay than did Hartsells and Sequoia. Memphis and Maury showed a release of potassium at the low levels of added potassium when aged, therefore, the relationship of released potassium from Memphis and Maury could follow the same conclusions made by Cook and Hutcheson (10), that illite is the probable site of potassium supplying power and that a relation exists between the illite content of the clay and the amount of potassium released from a soil.

The failure to obtain a more clear-cut relation between potassium supplying power and the mica minerals must be attributed to the lack of knowledge of the precise nature of the mica minerals. Less reasearch has been done on the silt and sand minerals; however, they sometimes contribute significantly to the fixation and release of potassium (4).

After comparing the results of potassium traced on the fresh soils and potassium traced on the soils after aging with the water soluble potassium of both, it was determined that the aging process

fixed the original and added potassium against isotopic exchange which is in agreement with the work of Attoe (3), Volk (47, 48) and Truog and Jones (44). It was found that aging caused a greater portion of the potassium that was traced on the fresh soil to be fixed against isotopic exchange for the zero level of potassium than for levels 1 and 2 except for the Hartsells soil. The fixed potassium for the zero level was the original soil potassium. For levels 1, 2 and 3, a larger portion of added potassium was exchangeable with K^{42} than was fixed after aging.

III. IONS DISPLACED BY ADDED POTASSIUM

An attempt was made by analyzing the soil extraction solution to determine if calcium, magnesium and hydrogen made up the bulk of ions displaced by the added potassium that was retained on the soil. Increasing amounts of calcium and magnesium were found in the extractant solution on all soils as the amounts of added potassium increased or as the amounts of potassium retained on the soil increased; however, no significant difference in amounts of hydrogen and chlorine were observed. Chlorine was determined to learn if there were any salt absorption as KCl by the soils. The procedures used to determine hydrogen ions were probably not accurate enough to give a dependable measure of the hydrogen ions displaced by potassium.

Of the retained potassium less than 50 per cent displaced calcium and magnesium on the fresh soil except for the high level of added potassium on M aury and the low level of added potassium on Baxter. For the age

soils, the retained potassium that displaced calcium and magnesium exceeded .50 per cent with the following treatments: all amounts of added potassium to the Hartsells soil, the low amount of added potassium to the Maury soil and the high amount of added potassium to the Memphis soil. One would expect hydrogen, aluminum, manganese and sodium to account for the remainder of the ions displaced by the potassium; however, small quantities of other ions may be displaced.

IV. ISOTOPIC EXCHANGE AS A FUNCTION OF TIME

It appeared from the data on elapsed time between adding the potassium treatments and K^{42} to the soil, that the amount of potassium traced on the soil increased from 1 hour to 12 hours and decreased from 12 hours to 24 hours. The soil was wetted by adding KCl in solution at time zero. This begins an equilibrium reaction of the added potassium between the water soluble, exchangeable and nonexchangeable forms. It appeared that the K^{42} equilibrated with a maximum amount of potassium in the soil around the 12 hour period. The equilibrium between water soluble and readily exchangeable potassium would take place in only a few minutes; therefore, the 1, 12 and 24 hour periods were a measure of the more difficulty exchangeable and the readily exchangeable potassium reactions.

The same general conclusions were drawn regarding the different shaking periods. These results could have been due to two time dependent reactions. Twelve hours of shaking may have been required to obtain

equilibrium with a maximum number of difficulty exchangeable potassium

ions in the soil. Further periods of contact may have resulted in

potassium fixation.

CHAPTER VI

SUMMARY

Experiments were conducted to study the behavior of added and of native potassium in five Tennessee soils and factors affecting potassium fixation and release by the soils. Relationships of clay mineralogy, aging, and potassium content of the whole soil and soil fractions to potassium fixation and release were investigated. The effects of shaking time and elapsed time between adding the potassium treatments and the radioactive isotope on isotopic exchangeable potassium, and the equivalents of ions displaced by adding potassium to the soil at the rates of .128, .256 and .512 meq./100 g. were studied. Short time plant uptake studies were conducted to determine plant response to the readily available potassium on the soils treated with zero, low, medium, and high levels of potassium.

The major results were as follows:

1. A positive relationship exists among the soils for the quantity of potassium: released by the boiling 1.0 N. HNO_3 extractant; retained on the soil after aging with the high level of added potassium; retained on the fresh soil for all levels of added potassium, and extracted from the clay fraction by total digestion.

2. There was no obvious relation among the soils between the total potassium and available potassium determined by the boiling 1.0 N. HNO_3 method.

3. A significant correlation of .85 exists between the soils for potassium released to sudangrass and potassium extracted by 1.0 N. $NH_4C_2H_3O_2$.

4. The potassium content of the silt fraction and of the total soil was related to the illite content of the clay fraction.

5. The potassium released to 0.1 N. naphthylamine-HCl, and boiling 1.0 N. HNO_3 was related to the potassium content of the clay fraction, to the clay content of the soil, and to the quantity of total potassium that came from the clay.

6. The amount of potassium retained on the soil was closely related with its clay content and clay mineralogy; also, as the added potassium increased the greater was the amount of potassium retained on the soil but the smaller was the percentage retained.

7. The quantity of added potassium retained due to aging was associated with the vermiculite to illite ratio of the soil clay. The greater the vermiculite to illite ratio the greater was the quantity of potassium retained on the soil.

8. Aging caused fixation of original and added potassium against isotopic exchange. The quantities fixed for the zero levels of potassium ranged from .116 to .360 meq./100 g.

9. The amount of potassium traced on the soil was greater for the 12 hour period of shaking and for the time elapsed between adding the potassium treatments and the K^{42} isotope than for either the shorter or longer periods.

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