August 2, 1948

To the Committee on Graduate Study:

I am submitting to you a thesis written by Raymond Harris Webster entitled "The Rate of Release of Potassium From Some Tennessee Soils." I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

E. Winters

Major Professor

We have read this thesis
and recommend its acceptance:

Floyd F. Beaty

E. C. Cogner

Accepted for the Committee

E. G. Waters

Dean of the Graduate School

THE RATE OF RELEASE OF POTASSIUM
FROM SOME TENNESSEE SOILS

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Raymond Harris Webster

August 1948

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Mr. O. H. Long for furnishing the data on crop response to fertilization for several of the soils.

— Raymond Harris Webster

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INTRODUCTION

The prupose of this study is to determine the rate of release of non-exchangeable to exchangeable potassium in different Tennessee soils.

The exchangeable potassium content of most Tennessee soils ranges from 50 to more than 200 pounds per acre in the surface layer. Thus, the amount of potassium in exchangeable form found at any one time is often less than that removed by one or a few crops at the most. In order that some of these soils may be cropped successfully for years without potassium fertilization, part of the potassium required by the crops must be supplied from the non-exchangeable form or forms in the soil. Wood and DeTurk (10)[1] have suggested that the following equilibrium exists among the potassium compounds of the soil: Primary Mineral Potassium $\longrightarrow$ Fixed Potassium (Acid-Insoluble) $\rightleftarrows$ Fixed Potassium (Acid-Soluble) $\rightleftarrows$ Replaceable Potassium $\rightleftarrows$ Water Soluble Potassium.

Proof of the release of exchangeable potassium from the non-exchangeable forms has been well established by a number of workers. Bray and DeTurk (4) leached different soils with 0.1 normal hydrochloric acid to remove replaceable potassium and then stored them in a moist condition for six months. They obtained releases ranging from 21 to 288 pounds per acre. The release of potassium from non-replaceable forms

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[1]Figures in parenthesis refer to literature cited in the Bibliography, page 16.

under the same conditions but where the original exchangeable potassium had not been removed was generally very small or negligible.

Abel and Magistad (1) in similar studies found that upon continuous cropping for 20 months, amounts of non-exchangeable potassium ranging from 132 to 238 pounds per acre were removed by the crops. York and Rogers (11) studied the influence of lime on the solubility of potassium in soils. They recorded the potassium released from non-exchangeable forms by six Alabama soils at 0, 75, and 150 per cent calcium saturation. Releases ranging from 32 to 88 pounds per acre at 0 per cent saturation were recorded over a period of 150 days. The releases were somewhat higher for the 75 and 150 per cent calcium saturated soils.

Bear, et al (2) conducted pot experiments on the potassium-supplying power of 20 New Jersey soils, both with and without potassium fertilization. Seven crops of alfalfa were grown and the amount of non-exchangeable potassium released during the entire period was calculated. It was concluded that more potassium was released on the no-potassium pots than on the potassium treated pots.

Chandler, et al (5) continuously cropped 11 New York soils with Ladino Clover for periods ranging from 271 to 391 days. Amounts of non-exchangeable potassium ranging from 16 to 358 pounds per acre were removed by the crops. The exchangeable potassium content of the different soils decreased very rapidly at first, then more gradually until a certain level was reached, where the potassium-supplying power of the soil was equal theoretically to the rate at which non-exchangeable potassium was converted into the exchangeable form.

MATERIALS AND METHODS

The soils selected for this study represent surface samples of series that are commonly encountered in Tennessee, with the exception of one sample from Illinois. Seven of the series are West Tennessee soils, namely, Center, Loring, Collins, Anguille, Obion, Memphis, and Eupora. The Hagerstown and Talbott series are found in both the Central Basin and the East Tennessee Valley while the Dickson is a Highland Rim soil. The other series are found in the East Tennessee Valley.

The original replaceable potassium level was determined by the following procedure: 20 grams of air-dry soil were extracted with 40 milliliters of neutral normal ammonium acetate. The filtrate was evaporated to dryness and then wet oxidized with nitric, perchloric, and sulfuric acids in the order listed. The residue after oxidation was dissolved in an extracting solution containing 0.1 normal free perchloric acid and approximately 25% sodium perchlorate. Potassium determinations were made by a modification of the method outlined by Bray (3). Turbidities were measured with a photolometer and the replaceable potassium in pounds per acre was read from a curve that had been constructed from results of determinations made on standard potassium chloride solutions.

The release of exchangeable potassium from non-exchangeable forms was determined as follows: After the 20 gram samples were extracted with ammonium acetate, they were leached with 0.1 normal calcium chloride solution (pH approximately 6.0) to remove ammonium ions and to give approximately 75 per cent calcium saturation. Finally, the samples were leached with water to remove soluble salts, then they were stored in a moist condition for varying periods of time. When the moist storage period was completed, the samples were again extracted with neutral normal ammonium acetate and the release of exchangeable potassium was determined by the same method as that used to determine the original replaceable potassium level.

Determinations on all samples were carried out in duplicate and the results shown are an average of the two determinations. Duplicates checking within 10 per cent were considered to be within the range of experimental error.

RESULTS

Table I gives the original replaceable potassium level of fifteen Tennessee soils, the release of potassium from non-exchangeable to exchangeable forms during 15 day moist storage periods, and the cumulative release values over a 45 day period.

The amount of potassium released ranged from 23 to 93 pounds per acre. Soils with an original level between 50 and 100 pounds per acre released from 23 to 31 pounds; soils with an original level between 100 and 155 pounds released from 32 to 41 pounds, with the exception of one soil that released 64 pounds; and soils with an original level over 155 pounds per acre released 40 pounds or more in all cases.

The data in Table II show the release of potassium from one Illinois and four Tennessee soils at various intervals of time after the original exchangeable potassium was removed. These figures were obtained during preliminary work and before a definite time interval was selected for the release studies. Releases ranging from 49 pounds over a 75 day period to 134 pounds over a 105 day period were obtained.

TABLE I

EXCHANGEABLE POTASSIUM CONTENT AND NON-EXCHANGEABLE POTASSIUM RELEASED FROM FIFTEEN TENNESSEE SOILS

Sample Number	Soil Series	Orig. Exch. K	Potassium Released 1st 15 Days	2nd 15 Days	3rd 15 Days	Total 45 Days	Crop Response to Potassium Fertilization
		Pounds Per Acre					
1239	Leadvale	165	3	14	23	40	No
1361	Center	155	12	9	8	29	Yes
1385	Loring	155	10	9	14	33	No
1408	Collins	200	48	13	9	70	No
1399	Anguille	153	8	15	12	35	No
1387	Obion	195	65	18	10	93	No
1578	Memphis	210	18	25	6	49	No
1586	Eupora	125	9	17	6	32	Yes
10	Dewey	118	16	20	5	41	Unknown
18	Decatur	148	42	16	6	64	Unknown

TABLE I

EXCHANGEABLE POTASSIUM CONTENT AND NON-EXCHANGEABLE POTASSIUM RELEASED FROM FIFTEEN TENNESSEE SOILS (continued)

Sample Number	Soil Series	Orig. Exch. K	Potassium Released 1st 15 Days	2nd 15 Days	3rd 15 Days	Total 45 Days	Crop Response to Potassium Fertilization
			Pounds	Per	Acre		
9	Tellico	170	19	16	8	43	Unknown
60	Hagerstown	67	10	17	4	31	Unknown
85	Dickson	75	5	9	9	23	Unknown
3	Talbott	165	39	40	9	88	Unknown
15	Fullerton	58	14	8	4	26	Unknown

TABLE II

EXCHANGEABLE POTASSIUM CONTENT AND NON-EXCHANGEABLE POTASSIUM RELEASED FROM FIVE SOILS

Sample Number	Soil Series	Orig. Exch. K	Potassium Released Between Sucessive Extractions 45 Days	30 Days	30 Days	15 Days	15 Days	Total	Crop Response to Potassium Fertilization
				Pounds	Per	Acre			
1238	Leadvale	170	50	—*	18	41	25	134	No
1362	Center	VH**	48	—*	30	23	19	120	Yes
M768	Drummer	200	40	—*	—*	30	24	94	Unknown
1587	Eupora	165	19	—*	—*	13	17	49	Yes
1409	Collins	VH**	—*	58	48	21	5	132	No

*Period Omitted.
**More than 210.

DISCUSSION

Several soils used in this study were specifically selected because data from field experiments on crop response to potassium fertilization were available from Mr. O. H. Long, of the Tennessee Agricultural Experiment Station. Such data make it possible to study the critical level of potassium for crops in relation to the rate at which the exchangeable potassium is replenished from the non-exchangeable forms in the soil.

Results from these field experiments are shown in Table III. The yields are an average of four replicates. The original replaceable potassium level of the check plots was determined by the same method used in this study. The same soil samples used by Mr. Long for determining original replaceable potassium were used for this experiment. A difference in exchangeable potassium, as determined for the two studies, will be noted for most of the soils. Mr. Long's values (Table III) were obtained two to three years previous to the determinations made for this study (Tables I and II). Values for some of the soils are higher by the later determination; some are the same or within the range of experimental error, while others are lower. For the soils with higher values by recent tests, it is suggested that some potassium was released from a non-exchangeable to a replaceable form during the two to three year dry storage period in the laboratory. For soils with lower values, it can be assumed that the soil potassium was not in equilibrium at the time of the first determination, due to past fertilization or sampling at a time when the replaceable level was

TABLE III

EXCHANGEABLE POTASSIUM AND RESPONSE OF CORN AND COTTON
TO POTASSIUM FERTILIZATION ON EIGHT SOILS

Soil Series	Sample Number	Orig. Exch. K of Check Plot	Crop Grown	Yields Per Acre* NPK Plots	NP Plots	Check Plots	Inc. From K	L. s. d. (5% Level)
	1238	95**						
Leadvale	1239	145	Corn	70.5	72.7	43.2	-2.2	11.2
	1361	130						
Center	1362	180	Corn	68.4	54.1	54.6	14.3	13.3
Loring	1385	110	Corn	81.3	86.5	33.2	-5.2	12.8
	1408	210						
Collins	1409	205	Corn	41.4	50.5	27.2	-9.1	17.8
Anguille	1399	135	Corn	92.4	91.7	68.1	0.7	15.6
Obion	1387	200	Corn	79.0	88.2	64.8	-9.2	20.2
Memphis	1578	VH***	Cotton	1702	1453	1273	249	318
	1586	165						
Eupora	1587	100	Cotton	2192	1512	1404	680	365

*Corn yields are expressed in bushels; cotton yields are expressed in pounds of seed cotton.
**Pounds per acre.
***More than 210.

high, and some of the potassium was fixed to non-exchangeable forms during the storage period. Similar results have been reported by Seatz and Winters (8). Further, it is suggested that the non-exchangeable and replaceable potassium were in equilibrium at the time of the first determination for the soil samples having similar values for both determinations.

Corn gave a yield response to potassium on one soil only and the increase was close to the least significant difference (l. s. d.) value. This one soil, the Center, had an original potassium level of 155 pounds with 29 pounds being released from non-exchangeable forms during the 45 day period of this study. Other soils having similar original potassium levels with slightly higher releases but which gave no response with corn are the Leadvale, Loring, and Anguille. These series had original levels of 165, 155, and 153 pounds with releases of 40, 33, and 35 pounds, respectively, over the 45 day period. These values for exchangeable potassium and for potassium release appear to be close to the critical values for corn under the experimental conditions, and corn response to fertilization would be doubtful under such conditions. These exchangeable potassium levels agree with the critical levels (155 pounds per acre) reported by Winters (9) for corn on Tennessee soils.

Other series used for the studies with corn were the Collins and Obion. The Collins had an original level of 200 pounds with 70 pounds being released over the 45 days while the Obion had an original level of 195 pounds with a release of 93 pounds. The original replaceable potassium level of these soils is well over the suggested critical level and release from non-exchangeable forms is high. Therefore, the lack of crop response to potassium fertilization on these soils was to be expected.

Only two soils were used for the field experiments with cotton. The Eupora series gave a yield response to potassium and the increase was considerably higher than the least significant difference. The Memphis did not give a yield response. Original potassium level of the Eupora was 125 pounds and 32 pounds were released. The Memphis had an original level of 210 pounds with 49 pounds being released. These data suggest that the Memphis level is above the critical value while the Eupora level is below the critical value for cotton. Winters (9) found the approximate critical level of exchangeable potassium for cotton to be 185 pounds.

Seven soils were used in this study for which no crop response results are available. Three of the series, Hagerstown, Dickson, and Fullerton, had original replaceable potassium levels below 100 pounds per acre and the release from non-exchangeable forms was low. It is expected that corn and cotton would respond well to potassium fertilization on these soils. Similar results have been reported by Hoagland and Martin (6), Murphy (7), and Winters (9).

The Dewey, Decatur, Talbott, and Tellico series had original levels of 118, 148, 165, and 170 pounds with releases of 41, 64, 88, and 43 pounds, respectively. No corn response would be expected on the Decatur and Talbott series and response would be doubtful with the Dewey and Tellico series.

The Leadvale, Center, Eupora, and Collins samples for which data are reported in Table II are from the same field, but represent different check plots than the samples of Table I. The difference in exchangeable potassium levels indicates the soil variability found within the area used for one field experiment.

The data in Table I indicate that soils with high release values during the initial release period will continue to have high values. Data for longer periods of time (Table II) likewise indicate that soils with high release values during the initial release period will continue to have high values over extended periods of time, whereas, soils with low release values during the initial period will continue to have low values over extended periods.

From the data presented here and those reported in the literature (1, 2, 3, 5, 7), it may be concluded that the amount of exchangeable potassium found in the soil at any one time may not always be a reliable measure of the capacity of the soil to supply potassium to the crop for any extended period of time and, consequently, is not always a good index, by itself, for suggesting rates of potassium fertilization. In many cases the rate at which the non-exchangeable potassium is converted into the exchangeable form should also be considered. However, more work must be completed, both with laboratory and field experiments, in order to determine more accurately critical release rates for various crops and for different soils.

SUMMARY

The original exchangeable potassium and the rate of renewal of exchangeable potassium after removal by ammonium acetate extracting solution were determined on fifteen Tennessee soils (eight with known crop response).

The major conclusions of the study may be briefly stated as follows:

1. The correlation between the original replaceable potassium level and the amount released from non-exchangeable forms was erratic in several instances.

2. Some soils were capable of releasing potassium over extended periods of time, and the conversion of non-exchangeable to replaceable potassium would probably be significant in crop production, particularly with soils exhibiting the higher releases.

3. Soils that had high release values during the initial release period continued to have high values over extended periods of time while soils with low release values during the initial period continued to have low values over extended periods of time.

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