DETERMINATION OF EXCHANGEABLE POTASSIUM IN SOIL AND RESPONSE OF CROPS TO POTASH FERTILIZATION

DETERMINATION OF EXCHANGEABLE POTASSIUM IN

SOIL AND RESPONSE OF CROPS TO POTASH FERTILIZATION

By

LLOYD B. MITCHELL

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1947

Submitted to the Department of Agronomy

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

For the degree of

MASTER OF SCIENCE

1949

Approved:

Horace J. Harper
In charge of thesis

H. F. Murphy
Head of Department of Agronomy

D. C. McIntosh
Dean of Graduate School

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Dr. Horace J. Harper for his encouragement and helpful criticisms in connection with this research study and in the preparation of this thesis.

TABLE OF CONTENTS

Page No.

INTRODUCTION

Exchangeable potassium in soil has been determined for many years by precipitation as cobalti-nitrite under controlled conditions. This method has some disadvantages. When the solution temperatures are high an increase in the solubility, of the Na-K-cobalti-nitrite occurs and low values are obtained. Consistent accurate results were difficult to secure by this method.

A new method based on the measurement of light intensity produced when potassium salts are volatilized in a flame has been developed by the Perkin-Elmer corporation.

Little information was available on the procedure to follow when this method was used for determination of exchangeable potassium in soil.

Since the determination of potassium by the flame photometer is a rapid procedure requiring only 2 or 3 minutes for a determination, the important problem in the use of this instrument is to discover a procedure which will completely remove the exchangeable potassium from the soil and to develop a satisfactory standard solution of potassium which will have the same viscosity as the solution being analyzed.

It is known that the total amount of potassium in the soil does not reflect accurately the amount of exchangeable potassium for plant growth. Studying the rate of release of potassium in fertile soils, many agricultural workers have found that the relative rate of liberation of potassium from soil minerals determines the continued richness of the soil. A high rate of liberation will maintain a high level of available potash and vice versa. What is actually available for the plant is the determing factor.

As successive crops are grown without return of potassium to the soil, the total exchangeable potassium is decreased and the rate of replacement will depend upon the movement of potassium from non-exchangeable forms to the surface of the clay complex.

The quantity of exchangeable potassium required for optimum growth of different crops is quite variable.

A part of this study will be to determine the quantity of exchangeable potassium in soil below which crops will respond to potash fertilization. In Oklahoma, where climatic conditions are quite variable, it would be expected that the climatic conditions for crop production would alter the relation between exchangeable potassium and fertilization.

In attempting to predict the need for potassium fertilization from the exchangeable potassium content of the soil it is necessary to know, (a) the critical level at which maximum yields cannot be maintained without the addition of potassium, and (b) the rate at which the exchangeable potassium is replenished by that from the non-exchangeable forms. Obviously, the response to potassium fertilization can be predicted with greater accuracy from the amount of exchangeable potassium when the content in the soil is either well below or well above the critical level. When the exchangeable potassium content is near the critical level, the potassium requirement of the soil cannot be evaluated properly without some knowledge of the rate at which the non-exchangeable potassium is converted into the exchangeable form.

Review of Literature

Three methods were used by Olsen and Shaw (25) in determining the available potassium in the soil and comparing these with crop response to potash fertilization. The three methods used were, (a) chemical, using neutral ammonium acetate, (b) the Mitscherlich method and (c) the Neubauer method. Their conclusion was, from this comparison of chemical and biological methods to field response, that each indicated a low supply of exchangeable potassium in soils on whoch crops were most responsive to potash fertilizers.

According to During, (10) who used the Mitscherlich method for determining available potassium, a surface soil in general should be fertilized if it contains less than about 175 pounds of exchangeable potash.

Fraps, (14) found a close relation between the exchangeable potassium in the soil and the potassium removed by crops. Evidence was presented to show that exchangeable potassium is used by the crops to a greater extent than other forms and that the exchangeable potassium is a measure of the strength of the soil as regards potassium. He states that the amount of potassium removed by crops is about twice the exchangeable potassium as determined by chemical methods. He found the correlation coefficient for the exchangeable potassium, as determined by extraction with ammonium chloride, and the amount of potash removed by crops, to be $.910 \pm .012$.

Magistad, (21) working with Hawaiian soils, found that continuous cropping for 20 months removed large amounts of non-exchangeable potassium, ranging from 132 to 238 pounds per acre.

Chandler, Peech, and Chang, (8) found that the change in the exchangeable potassium content of 28 soils on which alfalfa was growing vigorously showed an average decrease of 18 pounds per acre.

Hissink,(15) found that the amount of adsorbed potassium examined by him, averaged only 0.024 per cent, while the percentage of acid soluble potassium averaged 0.826 per cent, but considered the adsorbed portion of greater importance, so far as plant nutrition is concerned.

Bear, Prince and Malcolm,(6) found that there existed no correlation between the total potassium content and the yielding capacity of 20 of the most important New Jersey soils. The amount of exchangeable potassium was a more reliable index of the capacity of a soil to supply potassium for crop needs than total potassium.

Bray, (7) concluded that the amount of exchangeable potassium in the surface soils of the corn belt is directly related to the ability of the soil to supply potassium to crops. He found, that when soils contain 180 pounds of exchangeable potassium per acre, a corn yield of 90 per cent of optimum may be expected. The study of exchangeable potassium and crop response to potash fertilizers reveals a good correlation when the fertilizer is used in adequate amounts. It is shown that, through the use of the test for exchangeable potassium, estimations can now be made of,(a) the potash deficiency on each farm soil, (b) the yield increase to be expected on each, (c) the potash requirements for the majority of corn belt soils, and (d) the economics of potash use.

Dyer, (11) decided that if less than 200 pounds per acre of exchangeable potassium is found in a soil, as determined by extraction with 1 per cent citric acid, potassium fertilization is necessary.

Wood, (39) using 1 per cent citric acid as a solvent found that soils responding strongly to potash fertilizers yielded an average of 146 pounds per acre of exchangeable potassium and those that did not respond yielded on an average 280 pounds per acre of exchangeable potassium.

Wheeting, (37) reports that leaching a soil with normal ammonium chloride appears to be one of the best ways of determining the amount of exchangeable potassium in soils. The quantities of potassium made available by this means are quite closely related to the quantities obtained by plants themselves.

Murphy, (23) found that as a rule in mineral soils, it is not a matter of potash deficiency so much as it is of availability. The total potassium content of soils usually range from 10,000 to 60,000 pounds per 2,000,000 pounds of soil with the exception of peats, mucks, and some sandy soils, but the available supply may be limited even in those soils having the greater total supply. A relatively low nutritive level if constantly maintained will produce good crops, while a high quantity may not produce nearly as good a crop, if the solid phase does not contribute to it sufficiently to maintain it above the critical level. A good response was obtained from potash fertilization on soils containing under 60 ppm of exchangeable potassium. Response in many cases was obtained when the soil contained from 60 to 79 ppm of exchangeable potassium. Soils containing 80 to 99 ppm of exchangeable potassium were classified as doubtful, from 100 to 200 ppm very doubtful, and if a soil contained over 200 ppm of exchangeable potassium no response from potash fertilization would be secured.

Thornton, (32) using the seedling method on determining nutrient deficiencies in soils concluded that a minimum of 200 pounds per acre of exchangeable potassium is adequate for general farm crops in Indiana.

Scarseth,(26) found that when the soil contains 200 or less pounds per acre of exchangeable potassium additional potash will be needed by most crops.

Winters,(38) of Tennessee conducted field experiments to determine the response of several crops to potash fertilizers at different levels of available potash in the soil. Three treatments were given each field experiment,(a) no potash, (b) a medium potash application and, (c) a heavy application.

All plots, except in the case of alfalfa, were given uniform applications of nitrogen and phosphate to eliminate any serious deficiency of these two critical minerals. His conclusions are as follows: the approximate potassium requirements in pounds per acre for a 90 per cent optimum yield of corn is 155 pounds per acre, of alfalfa 160 pounds per acre, of cotton 185 pounds per acre and of Irish potatoes 220 pounds per acre.

Hoover,(19) working with Mississippi soils, reports that the crop requirement for a 90 per cent optimum yield of cotton is 180 pounds per acre of exchangeable potassium.

Olson,(25) of Georgia reports that the critical level of exchangeable potassium for a 90 per cent optimum yield of cotton is 175 pounds per acre.

Ensminger,(12) applied potash on a fine sandy soil which contained 56 pounds per acre of exchangeable potassium and increased the dry weight of lespedeza by 440 pounds per acre.

The conclusion of Bear,(5) was that about 160 pounds of readily exchangeable potassium per acre is needed for the production of normal yields of alfalfa, corn, and cereals.

A COMPARISON OF METHOD OF DETERMINATION OF EXCHANGEABLE POTASSIUM

Due to great difficulty in securing accurate results from using the sodium-cobalti-nitrite method, a flame photometer recently obtained from the Perkin-Elmer corporation was used to measure the exchangeable potassium removed from the soils studied in the following experiment.

A lack of detailed information on proper procedure to follow to obtain accurate measurements on exchangeable potassium in the soil made it necessary for considerable work on technique to be done.

Flame Photometer

In the operation of this instrument, the solution of potassium is atomized by a jet of air which carries the liquid into a Meker burner. A photoelectric measurement of light intensity produced is then made. The instrument is calibrated by means of a reference solution having a known concentration of potassium dissolved in a solution of the same viscosity as that used for extracting the soil. Table 1 gives the results of this calibration.

The accuracy of the measurements obtained by the use of the photometer will depend largely on the viscosity of the standards and unknowns which must be identical to obtain accurate results.

TABLE 1 POTASSIUM CONTENT OF SOLUTION BASED ON RHEOSTAT* READING ON THE FLAME PHOTOMETER CALCULATED FROM STANDARD SOLUTIONS OF POTASSIUM CHLORIDE IN AMMONIUM ACETATE

Rheostat Reading	ppm K	Rheostat Reading	ppm K	Rheostat Reading	ppm K
1	1.0	35	49.9	68	113.0
2	2.3	36	51.2	69	115.2
3	3.7	37	52.9	70	117.5
4	5.0	38	54.4	71	120.0
5	6.1	39	56.0	72	122.4
6	7.5	40	57.9	73	124.9
7	9.0	41	59.4	74	127.5
8	10.1	42	61.0	75	130.0
9	11.4	43	62.8	76	132.5
10	13.0	44	64.4	77	135.0
11	14.3	45	66.0	78	137.7
12	15.7	46	67.9	79	140.3
13	17.0	47	69.8	80	142.8
14	18.3	48	71.6	81	145.8
15	19.9	49	73.4	82	148.8
16	21.2	50	75.0	83	151.4
17	22.6	51	77.0	84	154.2
18	24.0	52	79.0	85	157.0
19	25.3	53	81.0	86	160.0
20	26.9	54	83.0	87	162.9
21	28.1	55	85.0	88	165.8
22	29.9	56	87.0	89	168.9
23	31.1	57	89.0	90	171.5
24	32.8	58	91.0	91	174.5
25	34.1	59	93.0	92	177.2
26	35.9	60	95.0	93	180.2
27	37.1	61	97.1	94	183.3
28	38.9	62	99.8	95	186.3
29	40.1	63	102.0	96	189.3
30	41.7	64	104.1	97	192.3
31	43.2	65	106.0	98	195.3
32	45.0	66	108.2	99	198.0
33	46.6	67	110.8	100	200.0
34	48.0				

* Local Citation

It has been found* that the potassium filter did not exclude all light emitted from sodium and some correction is necessary for potassium when more than a trace of exchangeable sodium is present.

Comparison of Cold Extraction and Leaching

Several comparisons were made of extracting the soil with 2N ammonium acetate, using one part of soil and two parts of the extracting solution, and leaching the soil with 2N ammonium acetate.

The procedure for the extraction with the 2N ammonium acetate was to place 5 grams of soil in a large test tube or beaker containing 10 cc. of the ammonium acetate. The suspension was stirred a minimum of four times and allowed to set for at least thirty minutes, before being filtered, and the potassium determined in the filtrate with the flame photometer.

The procedure for the leaching of the soil was as follows: a small piece of cotton was placed in the bottom of a leaching tube, 1 inch in diameter and four inches tall, to which was added a small amount of sand. The soil to be tested was placed on the sand and then more sand was placed on top of the soil. Ten cc. of the ammonium acetate was added to the tube and allowed to leach through the sand and soil. The leachate was then tested on the flame photometer. The results were then computed on the basis of the amount of leachate recovered, whereas in the method of extraction the results were computed on the amount of extracting solution originally used.

The conclusion from this experiment was that extraction was preferable in a routine analysis due to the saving of time.

---

* Local Citation

Since the exchangeable potassium is held on the surface of the clay particles, a study was made to determine whether a complete dispersion of the clay particles would increase the quantity of exchangeable potassium recovered from soils. A mechanical stirrer used in the hydrometer method for the mechanical analysis of soils, as recommended by Bouyoucos, was compared with hand stirring and the quantity of potassium extracted from these soils. The quantity of potassium extracted was the same and it was assumed that stirring for a minimum of four times was sufficient to disperse the soil.

Effect of Hot and Cold Extraction

Considerable time was spent in comparing hot and cold extraction of soils with 1N ammonium acetate as the extracting solution. This data is presented in Table 2.

The method of hot extraction was as follows: Twenty-five cc. of neutral 1N ammonium acetate was placed in a beaker or large test tube, 5 grams of 20 mesh soil was added and the beaker was placed in a water bath at 70 degrees centigrade and allowed to remain for one hour. This suspension was stirred a minimum of four times.

Table 2 A COMPARISON OF HOT AND COLD EXTRACTION

Soil No.	Hot Extraction K in ppm	Cold Extraction K in ppm
11730	85	57
11731	65	48
11735	155	100
11738	81	53
11741	150	106
11744	197	155
11749	78	65
11750	95	57
11752	91	71
11754	81	57
	Av. 110	Av. 77

The procedure for the cold extraction was carried out in the same manner as for the hot with the exception of the heating of the suspension.

For these particular soils hot extraction removed 30 per cent more potassium than did the cold. The conclusion reached was that hot extraction removed more replaceable potassium than cold extraction, but there was no definite relationship that could be established between the two methods.

TABLE 3 A COMPARISON OF REMOVAL AND NON-REMOVAL OF EXCHANGEABLE CALCIUM ON THE AMOUNT OF EXCHANGEABLE POTASSIUM WHEN DETERMINED WITH THE FLAME PHOTOMETER

Soil No.	Exchangeable Calcium removed K in ppm	Exchangeable Calcium Present K in ppm
11734	30	18
11735	155	125
11736	25	21
11737	30	30
11738	81	65
11739	65	41
11740	30	25
11741	150	135
11742	71	71
11743	70	38
11744	197	150
11745	30	38
11746	41	50
11747	65	65
11748	65	57
11749	78	71
11750	95	85
11751	71	65
11752	91	78
11753	71	50
11754	81	88
11755	30	41
	Av. 74	Av. 63

The Effect of the Removal of Exchangeable Calcium on the Determination of Exchangeable Potassium

During the course of the study, an attempt was made to determine if other bases, such as calcium and magnesium, were being removed in sufficient quantities to affect the accuracy of the potassium determination. The approximate amount of exchangeable calcium to be found in the average soil was estimated and this amount (.176 grams) was added to twenty five cc. of neutral 1N ammonium acetate. The photometer reading was similar to a 15 ppm solution of potassium. When the calcium was removed by the addition of a saturated solution of ammonium oxalate the photometer did not register.

When a similar amount of magnesium acetate was placed in 25 cc. of neutral 1N ammonium acetate and tested on the photometer there was no indication of any interference by this base.

Replaceable calcium was removed from twenty two soils by the addition of a saturated solution of ammonium oxalate. The soils were extracted hot with neutral 1N ammonium acetate, filtered, the ammonium oxalate was added, the exchangeable calcium was removed by filtering and the filtrate was measured by the photometer. The same soils were extracted hot with neutral 1N ammonium acetate and the exchangeable calcium was not removed. Table 3 gives the results of this experiment. When the calcium was not removed, the potassium content of the soil was 15 per cent more, than the soils which contained calcium. An attempt was made to remove the calcium by adding ammonium oxalate with the extracting solution. The ammonium oxalate formed crystals in the tip of the atomizer and made it very difficult to obtain accurate readings.

The conclusion reached on this part of the experiment was that calcium did have a slight interfering affect, but that it was a relative matter and that the removal of it would prove to be more time consuming than would be justified by the results obtained.

A Comparison of Various Extracting Solutions Used
For the Replacement of Exchangeable Potassium From Soils

Several extracting solutions have been used for the removal of replaceable soil potassium. The extraction of soils with .5N hydrochloric acid was tried. Five grams of 20 mesh soil was placed in 50 cc. of .5N hydrochloric acid and the solution was placed in a water bath for one hour. The temperature was kept at 70 degrees centigrade. After being removed from the water bath the solution was neutralized and the iron and aluminum filtered off. The filtrate was tested on the flame photometer. The results were erratic when compared with the results of the same soils extracted hot with 1N ammonium acetate.

Several attempts were made to extract the soils with 1N and 2N ammonium chloride. These solutions were not satisfactory because they would clog the atomizer before it could be standardized.

Mono-ammonium phosphate was tried as an extracting solution but there was not sufficient volatilization of the potassium combined with the phosphate to give readings equivalent to filtrates obtained by treating soils with ammonium acetate.

Considerable work was done using ammonium nitrate, both 1N and

2N as the extracting agent, and it was found to be equal to either 1N or 2N ammonium acetate. The results of the data on this are given in Table 4.

TABLE 4 A COMPARISON OF EXCHANGEABLE POTASSIUM EXTRACTED FROM FOUR SOILS BY 1N AND 2N AMMONIUM ACETATE AND 1N AND 2N AMMONIUM NITRATE

Soil	Ammonium Acetate		Ammonium Nitrate	
	1N	2N	1N	2N
	K in ppm			
Dennis Silt Loam	34	35	37	37
Parsons Silt Loam	30	34	35	35
Vanos Silt Loam	60	63	67	67
Summit Clay Loam	59	55	65	67

In the above case the ammonium nitrate extracted slightly more potassium than the ammonium acetate. However, for several other soils measured, there seemed to be no advantage, of one of these extracting solutions over the other, for routine analysis of exchangeable potassium. If ignition of the filtrate is desired for further tests the ammonium acetate would be preferable to use.

TABLE 5 A COMPARISON OF EXCHANGEABLE POTASSIUM EXTRACTED FROM FOUR SOILS USING 1N AMMONIUM ACETATE AND A 1 TO 2 AND A 1 TO 5 RATIO BETWEEN THE SOIL AND EXTRACTING SOLUTION

Soil	1 to 2 Ratio K in ppm	1 to 5 Ratio
Dennis Silt Loam	31	35
Parsons Silt Loam	25	34
Vanos Silt Loam	58	63
Summit Clay Loam	58	55

The Effect of Varying the Quantity of Ammonium Nitrate and Ammonium Acetate Solutions on the Removal of Exchangeable Potassium

A comparison was made to determine the correct ratio between the soil and the extracting solution, to obtain maximum amounts of exchangeable potassium. In Table 5 is given the results obtained from four soils. The 1 to 5 ratio extracted more potassium than the 1 to 2 ratio. A 1 to 10 soil-extracting solution ratio was studied but it is believed, that in the very low potash soils, this dilution is too great to give accurate readings on the flame photometer. The 1 to 5 ratio was used in measuring the soils with which potash experiments had been conducted.

TABLE 6 A STUDY OF THE POTASSIUM REMOVED FROM SOIL BY ONE EXTRACTION AND TWO SUCCESSIVE LEACHINGS WITH NEUTRAL 1N AMMONIUM ACETATE

Soil No.	Orig. Extraction K in ppm	1st Leaching	2nd Leaching
1	75	8	5
2	100	11	2
3	78	11	2
4	78	18	2
5	41	5	2
6	48	5	2
7	78	25	5
8	50	8	2
9	150	25	5

A Study of Soil Extraction Followed by Leachings on the Removal of Exchangeable Potassium

A study was made to determine if all of the exchangeable potassium was removed with the original extraction. The procedure for this study was as follows: the original extraction was made by the hot extraction method, as previously described in this study. The filter paper containing the soil left after the original filtering, was washed with 25 cc. of hot neutral 1N ammonium acetate, and this filtrate was measured on the photometer. The filter paper was washed again and this filtrate was again tested on the flame photometer. As Table 6 shows, all of the exchangeable potassium is not removed by the original extraction, but the first washing of 25 cc. removed practically all of the potassium.

TABLE 7 A COMPARISON OF 100 AND 200 PART PER MILLION OF POTASSIUM AS STANDARD REFERENCE SOLUTIONS

Soil No.	200 ppm Standard	100 ppm Standard
	K in ppm	
11726	10	15
11727	30	32
11728	78	78
11729	57	57
11730	71	57
11731	71	57
11732	54	60
11733	54	60
	Av. 53	Av. 52

The Effect of Varying the Concentration

of the Standard Reference Solutions

A comparison of using standard reference solutions containing 100 ppm of potassium and that containing 200 ppm of potassium was made. Table 7 shows that there is very little difference between using the two standard reference solutions. The important consideration in using the standard reference solutions, is that they be of the same viscosity as the extracting solutions. When 50 ppm of potassium was tried as a reference solution on the photometer, the sensitivity was reduced sufficiently to offset any advantage of the lower standard.

EXCHANGEABLE POTASSIUM AND CROP RESPONSE TO POTASH FERTILIZER

Most of the soils that were studied in this experiment were out of state soils. These soils had been tested for their crop response to potash fertilization. In attempting to determine critical levels of exchangeable potassium, from the data secured from these soils, it must be remembered that the climatic conditions and soil capabilities for the areas from which these soils were obtained are different from those prevailing in Oklahoma. The review of literature, on the subject of exchangeable potassium and crop response, did not reveal that this factor had been considered to any degree. The soils obtained from Illinois and Tennessee, on which the response of corn to potash fertilizer had been determined, were soils capable of producing 80 to 90 bushels of corn per acre. There are large acreages of corn planted on soils which are not capable of producing this much corn and therefore, the critical level of exchangeable potassium below which corn would respond to potash fertilization would be somewhat lower.

Response of Cotton to Potash Fertilizer

There were seventeen soils studied that had a known response, or lack of response, of cotton to potash treatment.

Three of the soils were from the Experiment Station of South Carolina. Nitrogen and phosphate were used in connection with potash in this series of experiments. Two of these soils that responded to potash tested low on the flame photometer and the third tested on the border line, of the tentative values set up for critical levels of exchangeable potassium as regards cotton. Data for the response of cotton to potash fertilization is given in Table 8.

Three of the soils that had a potash history for response to cotton were from Georgia. The soil from Avera, Georgia had 32 pounds of nitrogen applied to it along with 24 pounds of potash fertilizer and 48 pounds of potash fertilizer. Where 24 pounds of potash was applied there was an increase of 452 pounds of seed cotton per acre and where 48 pounds of potash was applied there was an increase of 502 pounds of seed cotton per acre. The flame photometer showed that there were 37 pounds per acre of exchangeable potash in the untreated soil.

The soil from Louisville, Ga., that had been treated with three different rates of potash and showed no response to treatment, tested 311 pounds of exchangeable potassium per acre on the flame photometer.

The soil from Rover, Georgia, that showed a response of 210 pounds of seed cotton per acre from 48 pounds of potash, contained 75 pounds of exchangeable potassium per acre. Two soils from Fayetteville, Arkansas, that showed a response to potash fertilization when cotton was planted, contained 157 and 130 pounds of exchangeable potassium per acre.

The Oklahoma soil that showed the greatest response to potash fertilization from cotton is located on the John Every farm near Checotah. This response was 330 pounds per acre of seed cotton. The soil measured only 37 pounds per acre of exchangeable potassium.

From the limited amount of data available, cotton response to potash fertilization, on soils containing varying amounts of exchangeable potassium, would be as follows: soils with less than 100 pounds of exchangeable potassium per acre should show a high response to potash application. Soils that contain from 100-150 pounds of potassium per acre should give a moderate response. Soils that contain from 150-190 pound per acre of exchangeable potassium should show slight response and soils above 190 pound per acre will show no response.

TABLE 8 RESPONSE OF COTTON TO POTASH FERTILIZATION

Soil No.	Location	Increase in Seed Cotton per Acre From Potash Use	Exchangeable K in pounds per acre
11726	Sandhill Expt. S. Car.	426 Pounds	37
11728	Pendleton, S. Car	460	170
11729	Abbeville Co. S. Car.	451	101
11734	Avera, Ga.	502	37
11735	Louisville, Ga.	No Response	311
11736	Rover, Ga.	210	75
11738	Fayetteville, Ark.	Moderate Response	157
11739	Fayetteville, Ark.	Moderate Response	130
7705	Sallisaw, Okla.	100	75
513	Stigler, Okla	250	170
470	Shawnee, Okla.	Moderate Response	157
835	Stigler, Okla.	Moderate Response	114
K 1	Checotah, Okla.	330	37
9041	Sallisaw, Okla.	Moderate Response	101
K 4	Spaulding, Okla.	175	163
8992	Hugo, Okla.	No Response	199
9022	Checotah, Okla.	Severe Leaf Rust	61

Response of Corn to Potash Fertilization

There were eleven soils tested for exchangeable potassium that had a cropping history of corn and its response to potash treatment. Eight of the soils were from out of state. There were four soils from the Tennessee Experiment Station. The flame photometer measurements agreed rather closely with the exchangeable potassium tests, on these soils made at this Station. The test included a comparison of nitrogen and phosphorus with nitrogen, phosphorous and potash. The results are given in Table 9.

Three soils with potassium records were from the Illinois Experiment Station in Urbana. The photometer tests agreed rather closely with their results. The two soils that showed a high response to fertilization tested very low in exchangeable potash, containing 37 and 68 pounds per acre respectively, while the soil with no crop response measured 299 pounds per acre of exchangeable potassium.

The soil from Wooster, Ohio, that had a response of 8.18 bushels per acre, measured only 56 pound per acre of exchangeable potassium on the flame photometer.

There has not been too much experimentation for corn response to potash in Oklahoma. Of the two soils noted there was a slight response where the soil tested 37 pounds per acre and no response on the soil testing 56 pounds per acre. The soil that gave no response to potassium gave a high response to nitrogen and phosphorus.

From the data available, it would seem that in general a moderate response would be obtained from corn growing on soils containing less than 140 pound per acre of exchangeable potassium and a slight response obtained from soils measuring 140-170 pound of exchangeable potassium per acre and no response to soils containing over 170 pound per acre. The values cited are obtained from soils that have productive capabilities of 80 bushels per acre or more. On soils of lower fertility and less favorable climatic conditions the critical lower limits would be reduced somewhat.

TABLE 9 RESPONSE OF CORN TO POTASH FERTILIZATION

Soil No.	Location	Increase in Corn From Potash Fertilization Bu. per Acre	Exchangeable K in pounds per acre
11730	Knoxville, Tenn.	10.4	170
11731	Knoxville, Tenn.	12.8	130
11732	Knoxville, Tenn.	7.0	130
11733	Knoxville, Tenn.	10.5	143
11740	Urbana, Ill.	22.0	37
11741	Urbana, Ill.	No Response	299
11745	Urbana, Ill.	20	68
11756	Wooster, Ohio	8.8	56
11624	Atoka, Okla.	4.0	37
K 6	Atoka, Okla.	No Response	56
1024	Remington, Ind.	Moderate Response	75

Response of Oats to Potash Fertilization

There were twelve soils available for study that had a cropping record of oat response to potash treatment. Of these twelve soils, five were from out of state and seven were from Oklahoma. There was only one soil in this group that had a record of a high response to potash treatment and this soil was from Ewing Field, of the Illinois Experiment Station. This soil was very responsive to potash on corn, wheat and oats. The increase in oat yield was 7 bu. per acre. The flame photometer measurement on this soil agreed very closely with that of the tests of the Illinois Station, where the cobalti-nitrite method for the determination of potassium was used. Their test showed 40 pounds per acre of exchangeable potassium while the photometer measured 37 pounds per acre. There were only two other soils that showed a slight response and the values for these were 68 and 56 pound per acre respectively. Data for this are given in Table 10.

It would seem from these data that oats are capable of using more of the slowly available potassium than many other field crops.

From the data available, oats would probably give a moderate response to potash treatment from soils containing less than 60 pounds per acre of potassium, a very slight response to soils containing from 60 to 100 pounds per acre and no response to soils containing over 100 pounds per acre of exchangeable potassium.

TABLE 10 RESPONSE OF OATS TO POTASH FERTILIZATION

Soil No.	Location	Increase in Oats in Bushels per Acre	Exchangeable K in Pounds per Acre
11740	Ewing Fld. Urbana, Ill.	7	37
11741	Aledo Fld. Urbana, Ill.	No Response	299
11745	Toledo Fld. Urbana, Ill.	Slight Response	68
11751	Purdue Univ. Lafayette, Ind.	No Response	114
11756	Wooster, Ohio	Slight Response	56
7702	Okla. Expt. Sta. Morris, Okla.	No Response	226
9001	Vinita, Okla.	No Response	183
7708	Vinita, Okla.	No Response	96
9006	Delaware Co.	No Response	328
9031	Morris, Okla.	No Response	121
9052	Copan, Okla.	No Response	415
11613	Okla. Expt. Sta.	No Response	212

TABLE 11 RESPONSE OF WHEAT TO POTASH FERTILIZATION

Soil No.	Location	Increase in Wheat From Potash Fertilization in Bu. per Acre	Exchangeable K in Pounds per Acre
11740	Urbana, Ill.	9	37
11741	Urbana, Ill.	No Response	299
11745	Urbana, Ill.	6	68
11748	Lafayette, Ind.	Slight Response	101
11756	Wooster, Ohio	1.1	56
6644	Stillwater, Okla.	Slight Response	269

The data available for wheat response to potash treatment was very slight. There were only six soils that had any record of potash fertilization and crop response. Of these six, only three showed what might be considered a profitable response. Two soils from Illinois that showed only a slight increase from potash treatment for wheat and oats, showed a high response for corn.

It would seem from this data that wheat, like oats, has a rather low requirement for exchangeable potassium.

From the very limited data available, wheat could be expected to give a slight to moderate response to potash treatment from soils conteining less than 60 pounds per acre, a slight to very slight response from soils containing between 60 and 100 pounds per acre and no response to soils containing over 100 pound per acre of exchangeable potassium.

TABLE 12 RESPONSE OF ALFALFA TO POTASH FERTILIZATION

Soil No.	Location	Increase in Pounds of Alfalfa Hay from Potash Fertilization	Exchangeable K in Pounds per Acre
11737	DeKalb Co. Ga.	820	75
797	Jennings, Okla.	Slight Response	170
4439	Inola, Okla.	Showed Severe Leaf Symptoms of Potash Starvation	61
6473	Spencer, Okla.	No Response	850

Response of Alfalfa to Potash Treatment

There wereonly four soils available for study that had any crop record of response from alfalfa to potash fertilization. The soil from DeKalb Co. Georgia showed an increase of 820 pounds of hay per acre from an application of 100 pounds of potash. The potash was used in conjunction with borax and lime. The photometer showed this soil to be very low in exchangeable potassium as it contained only 75 pounds per acre of exchangeable potassium per acre. The soil from the H.C. Ruppel farm near Inola, developed leaf symptoms of potash starvation after lime and phosphate had been applied to it.

From this data alone it would be impossible to attempt to establish any values for potassium needs for alfalfa, but this study in its very limited scope does seem to agree rather closely with the results of other workers on the same subject.

TABLE 13 RESPONSE OF SWEET CLOVER TO POTASH FERTILIZATION

Soil No.	Depth	Increase in Pounds of Hay From Potash Treatment	Exchangeable K in Pounds per Acre
P 64	0-6"		—
P 65	6-12"	350	68
P 66	12-18"		56
P 67	18-24"		43
P 68	24-36"		50
P 216	0-6"	500-1500	233
P 217	6-12"		157
P 218	12-18"		157
P 219	18-24"		130
P 220	24-30"		161
P 221	30-36"		90
P 381	0-6"	500-1700	43
P 382	6-12"		30
P 383	12-18"		43

There were little data available for study on sweet clover and its response to potash. The above Table is more of a profile study than it is of potash study.

Further comparisons are needed before accurate data can be given for responses to be expected when sweet clover is planted on soils varying in exchangeable potassium.

Summary

A series of experiments were made to determine the exchangeable potassium content of several soils, and to determine the critical lower limit of exchangeable potassium, below which various field crops would respond to potash fertilization. The recently developed flame photometer method was used in this study.

Due to the comparative newness of this method of measurement of exchangeable potassium, it was necessary to develop a procedure for its efficient use.

The extraction of soils was found to be better than leaching for the removal of the exchangeable potassium.

Hot extraction of soils, whereby a water bath at 70 degrees centigrade was used for one hour, was found to extract a least 30 per cent more exchangeable potassium than cold extraction.

Neutral ammonium acetate and ammonium nitrate were found to be the best extracting solutions for the removal of exchangeable potassium from the soil. It was found that a 1N concentration of either of the above mentioned extracting solutions was sufficient for the removal of the maximum amount of exchangeable potassium.

It was found that a one to five ratio of soil to extracting solution was preferable over other ratios.

It was determined that all of the exchangeable potassium was not removed by the first extraction. The leaching of the soil with twenty five cc. of hot 1N ammonium acetate after the original extraction removed the greater part of the exchangeable potassium.

Exchangeable calcium was found to be extracted with the exchange-

able potassium, but it was determined that the removal of the calcium was not necessary for accurate routine analysis.

In order to obtain accurate results from the use of the flame photometer, it was found that the viscosity of the standard reference solutions must be the same as that of the extracting solutions used.

Either 100 ppm or 200 ppm of potassium can be used as the reference solution.

It was necessary to calibrate the flame photometer by comparing the rheostat readings calculated from standard solutions of potassium chloride in ammonium acetate.

A total of 53 soils that had a definite known response or lack of response from various field crops to potash treatment were studied. A majority of the soils were from states other than Oklahoma, where prevailing climatic conditions and soil capabilities are variable. This makes it difficult to establish critical levels of exchangeable potassium for Oklahoma from the data obtained from these particular soils.

From the data available, it seems that of the crops studied in this experiment cotton has the greatest need for exchangeable potassium. Alfalfa ranks second in its demands for exchangeable potassium, corn ranks third, wheat ranks fourth and oats and sweet clover seem to have more ability to obtain their potassium needs from the slowly available forms.

Literature Cited

1. Atoe, O.J., and Truog, E. Rapid photometric determination of exchangeable potassium and sodium. Soil Sci. Soc. of Amer. Proc. 11 (1946) 221-226

2. Atoe, O.J., and Truog, E. Exchangeable and acid soluble potassium as regards availability and reciprocal relationships. Soil Sci. Soc. of Amer. Proc. 10 (1945) 81-86

3. Anthony, R. D., Dunkle, E. C., and Merkle, F. G., Potash availability studies in Pennsylvania orchard soils. Amer. Soc. Agron. Jour. 31 (1939) 438-458

4. Bartholomew, R. P., and Janssen, George. The relation between concentrations of potassium in culture solutions and optimum plant growth. Soil Sci. 27 (1929) 189-203

5. Bear, Firman E. Alfalfa---the aristocrat. Better crops with plant food. May (1945) p.6

6. Bear, Firman E., Malcolm, John L., and Prince, Arthur L. The potassium supplying powers of 20 New Jersey soils. Soil Sci. 58 (1944) 139-149

7. Bray, Roger H., The quantitative relation of exchangeable potassium to crop yields and to crop response to potash additions. Soil Sci. 58 (1944) 305-324

8. Chandler, Robert F., Peech, Michael and Chang, C. W. The release of exchangeable and non-exchangeable potassium from different soils upon cropping. Amer. Soc. of Agron. Jour. 37 (1945) 709-721

9. DeTurk, E.E., Bray, R.H., and Wood, L.D. Potash fixation in corn belt soils. Soil. Sci. 55 (1943) 1-13

10. During, G. Das., Verfahren Mitscherlich. Honcamp F. Handbuch der pflanzenernahrung und dungerlehre 1 (1931) 858-881 (original not seen)

11. Dyer, B. The analytical determination of the probably available plant food in soils. Jour. Chem. Soc., London (1894) Mar., pp. 115-167 Abs. in E.S.R. 5 1013-1015

12. Ensminger, L.E. Potash for legume pastures in Florida. Better crops with plant food. 29 Feb. (1945) p. 25

13. Fraps, G.S. The active potash of the soil and its relation to pot experiments. Tex. Agri. Exp. Sta. Bul. 145 (1921)

14. Fraps, G.S. Relation of the water-soluble potash, the replaceable and acid-soluble potash to the potash removed by crops in pot experiments. Tex. Agri. Expt. Sta. Bul. 391 (1929)

15. Hissink, D.J. Method for estimating adsorbed bases in soils and the importance of these bases in soil economy. Translated and summarized by F.H. Smith Soil Sci. 15 (1923) 269-276

16. Hoagland, D.R., and Martin, J.C. Absorption of potassium by plants in relation to replaceable, and soil solution potassium. Soil Sci. 36 (1933) 1-33

17. Hoagland, D.R., and Johnston, E.W. Minimum potassium level required by tomato plants grown in water culture. Soil Sci. 27 (1929) 89-109

18. Hoffer, G.N. Potash fertilizers are needed on many midwestern farms. Better crops with plant food. 29 Aug. (1945)

19. Hoover, C. D. Profit on Miss. soils from one ton of potash under cotton Better crops with plant food. Nov. (1946) p.6

20. Jones, R. J., and Truog, E. Fate of soluble potash applied to soils Jour. Ind. and Eng. Chem. 30 (1938) 882-885

21. Magistad, O.C. The relation between replaceable potassium and field response to potash in Hawaiian soils Soil Sci. 37 (1934) 99-103

22. Mehlich, A., and Reed, J. Fielding The influence of degree of saturation, potassium level, and calcium additions on removal of calcium, magnesium and potassium Soil Sci. Soc. Amer. Proc. 10 (1945) 87-93

23. Murphy, H.F. The replaceable potassium content compared with field response to potash fertilization of some Oklahoma soils. Amer. Soc. of Agron. Jour. 26 (1934) 34-37

24. Nelson, W.L. Efficient fertilizers needed for profit in cotton Better crops with plant food May (1946)

25. Olsen, S.R., and Shaw, B.T. Chemical, Mitscherlich, and Neubauer methods for determining available potassium in relation to crop response to potash fertilization. Amer. Soc. of Agron. Jour. 35 (1943) 1-9

26. Scarseth, G.D. Why are corn belt soils becoming low in available potash? Better crops with plant food 24 April (1940) p. 17

27. Snider, H.J. Potassium, a key element Better crops with plant food 29 May (1945) p. 9

28. Snider, H.J. Potash treatment makes better sweet clover Better crops with plant food 30 April (1946) p.23

29. Snider, H.J. Soil requirements for red clover Better crops with plant food 30 Nov. (1946) p. 17

30. Stanford, George and Pierre, W.H. The relation of potassium fixation and ammonium fixation Soil Sci. Soc. Amer. Proc. 11 (1946) 155-160

31. Stephenson, R.E. Maintaining available potassium in soils Better crops with plant food 27 Nov. (1943) p.20

32. Thornton, S.F. Experiences with the Neubauer method for determining mineral nutrient deficiencies in soils Amer. Soc. of Agron. Jour. 23 (1931) 195-208

33. Truog, Emil Availability of essential soil elements a relative matter Proc. Soil Sci. Amer. 1 (1936) 135-142

34. Volk, N.J. Relation of exchangeable potassium in Alabama soils to needs of the cotton crop Amer. Soc. of Agron. Jour. 34 (1942) 162-170

35. Volk, G.W. The nature of potash fixation in soils Soil Sci. 45 (1938) 263-276

36. Volk, N.J. The fixation of potash in difficultly available forms in soils Soil Sci. 37 (1934) 267-287

37. Wheeting, Lawrence C. A study of methods for the determination of the available potassium of soils. Soil Sci. 29 (1930) 1-20

38. Winters, Eric Crop response to potassium fertilization Soil Sci. Soc. Amer. Proc. 10 (1945) 162-167

39. Wood, T.B. Available potash and phosphoric acid in soils Trans. Chem. Soc. 69 (1939) 287-292

TYPIST: Mrs. Paul K. Sloan