Fixation and Release of Potassium in Several Eastern Oklahoma Soils

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Introduction

The quantity of **total** potassium contained in most mineral soils is comparatively high in relation to the total content of other essential plant nutrients. However, the amount of **available** potassium for plant nutrition in a given soil may range from adequate to deficient although the total potassium content of the soil mineral particles may be relatively high.

Many soils also have the capacity to revert available forms of potassium to forms not available for plants to use. A knowledge of soil factors that influence the rates and amount of potassium release and fixation will contribute to improved fertilization and soil management practices.

The results of incubation and greenhouse experiments with several eastern Oklahoma soils are presented in this bulletin.* This research was undertaken to characterize factors that influence the potassium status of these soils and thereby aid in evaluating general problems of potassium fertilization and soil management in Eastern Oklahoma.

Literature Review

Extensive research on potassium and its behavior patterns in soils has been performed in recent times. Reitemeier (4) summarizes the reports of various workers and their findings on the forms of soil potassium, influence of other cations on forms of soil potassium, relation of soil micro-organisms to soil potassium, and the effect of aeration and compaction on availability of potassium. Lawton and Cook (2) summarized the findings of workers concerned with the role of potassium in plant growth, potassium deficiency symptoms, potassium uptake during plant growth, potassium requirements of various crops, and effect of soil and climatic factors on potassium absorption.

Murphy (1934) (3) investigated the response of corn, cotton, potatoes and sweet clover to various levels of replaceable potassium. He proposed the following: soils containing less than 60 lbs. exchangeable potassium

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per acre gave reliably good response to potassium fertilization, 60-79 lbs. response was fair 80-99 lbs. response doubtful; 100-124 lbs. response very doubtful; 125-199 lbs. ordinarily no response; and over 200 lbs., no response expected. Responses to potash fertilization were conditioned, in part, by the level of nitrogen and phosphorus in the soils studied.

Harper (1950) (1), compiling data obtained from analysis of 6,379 soil samples from various parts of Oklahoma found that 60 to 100% of the soils in the eastern one-third of the state fell into the category where crop response to applied potassium could be expected. 30 to 60% of the soils in the central one-third and 0 to 30% of the soils in the western one-third of the state were in this category. The response to potassium applications was found to be conditioned to a large degree by the type of crop grown and the climatic conditions prevailing during the growth cycle.

Experimental Procedures

Soil samples were taken from fields representative of Eufaula Sand, Bowie Sandy Loam, Darnell Sandy Loam, Parsons Silt Loam and Renfrow Loam soil series. Physical and chemical characteristics of these soils are presented in Table 1.

Incubation Studies

The objective of this study was to determine the amounts and rates of potassium release and fixation as a result of alternate freezing and thawing and wetting and drying in five soils that had received various chemical treatments before starting the incubation sequence.

Table 1.—Physical and Chemical Characteristics of Soils used in Incubation Studies and Greenhouse Experiments.*

	Texture (percent)					Milliequivalents per 100 Grams Soil						
	Sand	Silt	Clay	pH	Nitrogen (percent)	Exchange capacity	K	Ca	Mg	Na	H	P
Eufaula Sand	92.0	6.50	1.50	5.6	0.017	0.905	0.067	0.099	0.015	0.049	0.675	0.148
Bowie Sandy Loam	76.0	20.25	3.75	5.4	0.022	1.411	0.107	0.330	0.090	0.052	0.832	0.161
Darnell Sandy Loam	62.0	31.25	6.75	6.5	0.163	7.128	0.471	3.66	0.450	0.061	2.486	0.483
Parsons Silt Loam	36.25	54.50	9.25	5.8	0.077	5.775	0.128	3.30	0.700	0.162	1.485	0.230
Renfrow Loam	45.25	32.00	21.75	6.2	0.157	13.50	0.174	7.80	2.50	0.140	2.886	0.145

The three soil treatments employed in this study were as follows:

1. Soil incubated with no prior chemical treatment.
2. Soils incubated with exchange capacity of the soil saturated with hydrogen.
3. Soils incubated with exchange capacity of the soil saturated with calcium.

Soils were hydrogen saturated by leaching 100 gram portions of each soil with 0.1 N hydrochloric acid until no calcium was indicated in the leachate. The excess acid was removed by passing distilled water through the soil until no free chloride was indicated in the leachate.

Soils were calcium saturated by adding calcium oxide to provide an amount of calcium equivalent to the exchange capacity of each soil.

Three-hundred grams of the treated and untreated soils from each series were weighed into wide-mouth pint Mason jars and brought to a moisture content equal to twice the moisture equivalent of the particular soil. A sufficient number were prepared to have triplicate samples of each soil treatment available for the freezing and thawing and wetting and drying phases of the study. Jars of soil selected at random were weighed during the incubation study and no measurable amount of moisture loss could be detected.

The chemically treated soils were divided into two groups. The first was frozen for 72 hours at —26° C. and then allowed to thaw for 72 hours at room temperature. The lids were removed from the jars, and a weight of moist soil equivalent to 50 grams of oven dry soil was removed for analysis. The lids were replaced and the samples were then ready to begin the next freezing and thawing cycle.

Soils in the second group were moistened, sealed and allowed to stand for 72 hours at room temperature. The lids were then removed and the jars placed in an oven and the soil dried for 72 hours at 105° C. The jars were removed and allowed to cool to room temperature. 50 grams of soil were removed for analysis. The remaining soil was wetted up to the original moisture content and the lids replaced. The samples were then started on the next wetting and drying cycle. Available potassium and pH were determined at the end of the first, second, third, fourth and eighth cycles. The values reported in Table 2 represent the mean of three replications, on the Eufaula, Bowie, Darnell, Parsons and Renfrow soils.

Exchangeable potassium, as used throughout this study, is that potassium which is removed from a soil by extraction with neutral normal ammonium acetate. Potassium in the filtrate was determined with a Perkin-Elmer Flame photometer model 52-C, using lithium as the internal standard.

All pH determinations were made with a Beckman glass electrode pH meter model H_2.

Table 2.—The Effect of Alternate Freezing and Thawing and Wetting and Drying on Various Soil Types H† Saturated, Ca†† Saturated, Untreated (field pH) on Potassium Release and Fixation and Soil Reaction.*

Eufaula Sand

		End of First Cycle Lbs. K/Acre	pH	End of Second Cycle Lbs. K/Acre	pH	End of Third Cycle Lbs. K/Acre	pH	End of Fourth Cycle Lbs. K/Acre	pH	End of Eighth Cycle Lbs. K/Acre	pH
Freeze and Thaw	H† Sat.	17	4.3	15	4.9	16	5.0	18	5.0	24	5.3
	Lbs. K/Acre Fix. or Rel			(−2)		(+1)		(+2)		(+6)	
	Ca†† Sat.	36	7.6	39	7.7	39	7.6	41	7.7	46	7.7
	Lbs. K/Acre Fix. or Rel.			(+3)		(0)		(+2)		(+5)	
	Field pH	46	5.7	43	5.8	47	5.8	42	5.6	47	5.7
	Lbs. K/Acre Fix. or Rel.			(−3)		(+4)		(−5)		(+5)	
Wet and Dry	H† Sat.	24	4.9	22	4.8	22	5.1	21	5.1	20	5.1
	Lbs. K/Acre Fix. or Rel.			(−2)		(0)		(−1)		(−1)	
	Ca†† Sat.	40	7.6	45	7.5	40	7.5	35	7.4	33	7.4
	Lbs. K/Acre Fix. or Rel.			(+5)		(−5)		(−5)		(−2)	
	Field pH	42	6.0	37	6.2	41	6.4	41	6.5	40	6.4
	Lbs. K/Acre Fix. or Rel.			(−5)		(+4)		(0)		(−1)	

Bowie Sandy Loam

		End of First Cycle Lbs. K/Acre	pH	End of Second Cycle Lbs. K/Acre	pH	End of Third Cycle Lbs. K/Acre	pH	End of Fourth Cycle Lbs. K/Acre	pH	End of Eighth Cycle Lbs. K/Acre	pH
Freeze and Thaw	H† Sat.	22	4.4	28	4.8	24	4.9	24	4.8	29	4.9
	Lbs. K/Acre Fix. or Rel.			(+6)		(−4)		(0)		(+5)	
	Ca†† Sat.	71	7.4	74	7.3	79	7.4	72	7.3	75	7.4
	Lbs. K/Acre Fix. or Rel.			(+3)		(+5)		(−7)		(+3)	
	Field pH	77	5.2	74	5.5	77	5.5	72	5.3	77	5.5
	Lbs. K/Acre Fix. or Rel.			(−3)		(+4)		(−5)		(+5)	
Wet and Dry	H† Sat.	29	4.8	34	4.8	32	5.1	27	4.8	34	4.8
	Lbs. K/Acre Fix. or Rel.			(+5)		(−2)		(−5)		(+7)	
	Ca†† Sat.	71	7.2	73	7.5	73	7.1	70	7.0	65	7.0
	Lbs. K/Acre Fix. or Rel.			(+2)		(0)		(−3)		(−5)	
	Field pH	72	5.7	71	5.9	75	6.4	74	6.3	75	6.4
	Lbs. K/Acre Fix. or Rel.			(−1)		(+4)		(−1)		(+1)	

* Potassium fixation as used herein refers to the conversion of water soluble and exchangeable potassium to forms not extractable with 1.N ammonium acetate, pH 7.0. A cycle as used herein is 144 hours for both freezing and thawing and wetting and drying phases, (−) indicates fixation, (+) indicates release. Each value reported is the mean of three replications.

		End of First Cycle Lbs. K/Acre	pH	End of Second Cycle Lbs. K/Acre	pH	End of Third Cycle Lbs. K/Acre	pH	End of Fourth Cycle Lbs. K/Acre	pH	End of Eighth Cycle Lbs. K/Acre	pH
	Darnell Sandy Loam										
Freeze and Thaw	H† Sat.	77	4.3	84	4.7	94	4.8	87	4.7	88	4.7
	Lbs. K/Acre Fix. or Rel.			(+7)		(+10)		(−7)		(+1)	
	Ca†† Sat.	285	7.4	358	7.4	387	7.5	395	7.5	376	7.5
	Lbs. K/Acre Fix. or Rel.			(+73)		(+29)		(+8)		(−19)	
	Field pH	343	6.7	434	6.8	478	6.8	389	6.7	411	6.8
	Lbs. K/Acre Fix. or Rel.			(+91)		(+44)		(−89)		(+22)	
Wet and Dry	H† Sat.	102	4.6	114	4.7	111	5.0	128	5.1	129	5.1
	Lbs. K/Acre Fix. or Rel.			(+12)		(−3)		(+17)		(+1)	
	Ca†† Sat.	320	7.4	400	7.5	363	7.2	409	7.6	412	7.7
	Lbs. K/Acre Fix. or Rel.			(+80)		(−37)		(+46)		(+3)	
	Field pH	362	6.6	402	6.5	371	6.5	421	6.8	423	6.8
	Lbs. K/Acre Fix. or Rel.			(+40)		(−31)		(+50)		(+2)	
	Renfrow Loam										
Freeze and Thaw	H† Sat.	75	3.9	85	4.4	95	4.7	85	4.4	84	4.4
	Lbs. K/Acre Fix. or Rel.			(+10)		(+10)		(−10)		(−1)	
	Ca†† Sat.	101	7.7	121	7.6	113	7.4	102	7.3	104	7.4
	Lbs. K/Acre Fix. or Rel.			(+20)		(−8)		(−11)		(+2)	
	Field pH	97	6.3	108	6.6	110	6.7	101	6.3	105	6.4
	Lbs. K/Acre Fix. or Rel.			(+11)		(+2)		(−9)		(+4)	
Wet and Dry	H† Sat.	129	4.4	161	4.4	151	4.7	158	4.7	169	4.7
	Lbs. K/Acre Fix. or Rel.			(+32)		(−10)		(−7)		(+11)	
	Ca†† Sat.	163	7.5	192	7.7	179	7.2	178	7.1	188	7.2
	Lbs. K/Acre Fix. or Rel.			(+29)		(−13)		(−1)		(+10)	
	Field pH	195	5.7	219	5.7	206	6.1	211	5.7	217	6.1
	Lbs. K/Acre Fix. or Rel.			(+24)		(−13)		(+5)		(+6)	
	Parsons Silt Loam										
Freeze and Thaw	H† Sat.	26	4.1	33	4.5	34	4.7	34	4.7	34	4.7
	Lbs. K/Acre Fix. or Rel.			(+7)		(+1)		(0)		(0)	
	Ca†† Sat.	74	7.4	82	7.4	81	7.3	74	7.3	75	7.4
	Lbs. K/Acre Fix. or Rel.			(+8)		(−1)		(−7)		(+1)	
	Field pH	84	6.4	90	6.5	91	6.5	89	6.5	89	6.5
	Lbs. K/Acre Fix. or Rel.			(+6)		(+1)		(−2)		(0)	
Wet and Dry	H† Sat.	48	4.5	53	4.5	48	4.8	39	4.3	62	4.5
	Lbs. K/Acre Fix. or Rel.			(+5)		(−5)		(−9)		(+23)	
	Ca†† Sat.	86	7.6	95	7.5	87	7.5	72	7.4	88	7.5
	Lbs. K/Acre Fix. or Rel.			(+9)		(−8)		(−15)		(+16)	
	Field pH	95	6.1	99	6.3	90	6.4	75	6.1	87	6.3
	Lbs. K/Acre Fix. or Rel.			(+4)		(−9)		(−15)		(+12)	

Greenhouse Studies

The objective of this portion of the investigation was to determine the effects of two levels of potassium fertilization on crop growth when applied with and without lime, nitrogen and phosphorus.

The four soils Eufaula, Bowie, Darnell & Parsons were selected for this study, varied in texture, organic matter, soil reaction and fertility level as indicated by the summary of their physical and chemical properties presented in Table 1.

Ammonium nitrate, monocalcium phosphate, potassium chloride and calcium carbonate were added in various combinations to these soils at rates equivalent to 50 pounds of N, 200 pounds of P_2O_5, and 100 and 200 pounds of K_2O calculated on an acre basis. Lime was applied at a rate equivalent to 4, 4 and 2 tons per acre on the limed pots of the Eufaula, Bowie, and Darnell soil series respectively.

These three soils were potted, treated as previously described, and brought to a moisture content of approximately 75 percent of their field capacity with distilled water. A sufficient number of one-gallon glazed earthenware pots were prepared to enable all treatments to be

EUFAULA, BOWIE and DARNELL—SOYBEANS

Table 3.—The Effects of Various Fertilizer and Lime Additions on the Soil pH, Available Potassium Content and the Yield of Soybeans in Greenhouse Experiments on Eufaula, Bowie and Darnell Soils.*

Treatments (Unlimed)	Yield in Grams	Avail. K Lbs./A.	Soil pH	Treatments (Limed)	Yield in Grams	Avail. K Lbs./A	Soil pH
			Eufaula Sand				
Check	1.23	45	6.0	L	1.66	43	7.45
N+P	1.10	46	6.10	L+N+P	2.30	45	7.05
N+P+K_1	1.00	118	6.20	L+N+P+K_1	2.70	107	7.0
N+P+K_2	1.50	147	5.90	L+N+P+K_2	2.57	118	7.0
			Bowie Sandy Loam				
Check	3.07	71	5.85	L	3.90	76	7.45
N+P	2.73	76	5.60	L+N+P	4.60	78	7.45
N+P+K_1	2.93	118	5.50	L+N+P+K_1	4.07	112	7.30
N+P+K_2	3.10	173	5.50	L+N+P+K_2	3.47	166	7.20
			Darnell Sandy Loam				
Check	4.93	364	6.6	L	5.03	356	7.45
N+P	7.07	356	6.45	L+N+P	7.30	356	7.45
N+P+K_1	6.47	426	6.50	L+N+P+K_1	6.63	412	7.30
N+P+K_2	6.73	464	6.40	L+N+P+K_2	6.67	449	7.20

*Yields and soil analyses represent the mean of three replicates. Soybeans planted 4-14-53, harvested 5-28-53.
L=Lime, Eufaula – 4 Tons/A., Bowie – 4 Tons/A., Darnell – 2 Tons/A.
N=Nitrogen (50#/A. elemental N)
P=Phosphorus (200#/A. P_2O_5)
K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

made in triplicate. The pots were planted to Lincoln soybeans, (**Glycine max**). After the seedlings were growing well, they were thinned to five plants per pot.

On May 29, 1953, the above ground portions of the plants were harvested. The relative growth of the crop, (as indicated by the dry weight of plant tissue), the soil pH and the available soil potassium are presented in Table 3.

The soil from each pot was thoroughly mixed and a sample taken from each of the three replicates. After sampling, the soils were returned to their original pots and prepared for planting of blackeye cowpeas (**Vigna sinenses**).

Analyses of the harvested plant tissue of the soybean crop for nitrogen, phosphorus, potassium, calcium, magnesium, and sodium are presented in Tables 9, 10, and 11.

Blackeye cowpeas were then planted and grown in the same manner as the soybeans. The relative growth of this crop, the soil pH and available soil potassium are presented in Table 4.

Analyses of the harvested plant tissue of this crop for nitrogen, phosphorus, potassium, calcium, magnesium, and sodium are presented in Tables 9, 10, and 11.

EUFAULA, BOWIE and DARNELL—SOYBEANS

Table 4.—The Effects of Various Fertilizer and Lime Additions on the Soil pH, Available Potassium Content and the Yield of Blackeye Cowpeas in Greenhouse Experiments on Eufaula, Bowie and Darnell Soils.*

Treatments (Unlimed)	Yield in Grams	Avail. K Lbs./A.	Soil pH	Treatments (Limed)	Yield in Grams	Avail. K Lbs./A	Soil pH
			Eufaula Sand				
Check	3.3	52	5.60	L	2.57	58	7.40
N+P**	---	53	5.70	L+N+P	3.17	56	6.25
$N+P+K_1$**	---	101	5.65	$L+N+P+K_1$	4.73	99	7.10
$N+P+K_2$**	---	138	5.80	$L+N+P+K_2$	4.50	109	7.00
			Bowie Sandy Loam				
Check	4.47	60	5.30	L	4.23	65	7.60
N+P	5.30	59	5.35	L+N+P	4.00	67	7.35
$N+P+K_1$	5.13	99	5.20	$L+N+P+K_1$	4.97	78	7.40
$N+P+K_2$	5.47	132	5.25	$L+N+P+K_2$	4.60	97	7.30
			Darnell Sandy Loam				
Check	4.03	365	6.5	L	2.03	348	7.20
N+P	3.30	373	6.25	L+N+P	3.67	340	7.10
$N+P+K_1$	5.10	413	6.35	$L+N+P+K_1$	3.97	340	7.10
$N+P+K_2$	4.17	493	6.05	$L+N+P+K_2$	4.53	381	7.0

*Yields and soil analyses represent the mean of three replicates. Crop planted 6-6-53, harvested 7-12-53.
**Crop failure resulting from Red Spider damage.
L=Lime, Eufaula – 4 Tons/A., Bowie – 4 Tons/A., Darnell – 2 Tons/A.
N=Nitrogen (50#/A. elemental N)
P=Phosphorus (200#/A. P_2O_5)
K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

The soils were sampled and mixed in the same manner as after the soybean crop. In addition, a second application of the original rates of N, P, and K was added to the appropriate pots. No further addition of lime was made.

The fourth soil, Parsons silt loam was included in the studies at this time. This soil was fertilized at the rate of 100 pounds of elemental N, 400 pounds of P_2O_5, 200 and 400 pounds of K_2O calculated on an acre basis. Four tons of lime, calculated on an acre basis, was added to the limed replicates.

All four soils were planted to Stokesdale tomatoes (**Lycopersicum esculentum**) and grown in essentially the same manner as were the preceding crops. Dry vegetative yields of tomato plants and available soil potassium are reported in Tables 5 through 8. The soils were sampled and mixed in the same manner as after the first crop.

All pots were then planted to Wintok oats (**Avena sativa**) and grown essentially as were the previous crops. Dry vegetative yields of the oats and available soil potassium after the crop was harvested are reported in Tables 5 through 8.

Experimental Results and Discussion

Incubation Studies

At the end of the first cycle all soils, except the calcium saturated Renfrow loam in the freeze and thaw phase (Table 2), exhibited a

EUFAULA, BOWIE and DARNELL—TOMATOES

Table 5.—The Effects of Various Fertilizer and Lime Additions on the Soil pH, Available Potassium Content and the Yield of Tomatoes in Greenhouse Experiments on Eufaula, Bowie and Darnell Soils.*

Treatments** (Unlimed)	Yield in Grams	Avail. K Lbs./A.	Treatments (Limed)	Yield in Grams	Avail. K Lbs./A.
		Eufaula Sand			
Check	0.88	42	L***	----	42
N+P	1.51	44	L+N+P	0.99	30
N+P+K_1	1.54	93	L+N+P+K_1	3.35	106
N+P+K_2	0.31	207	L+N+P+K_2	2.04	168
		Bowie Sandy Loam			
Check	****	64	L	1.10	63
N+P	****	59	L+N+P	2.42	54
N+P+K_1	****	144	L+N+P+K_1	2.12	111
N+P+K_2	****	180	L+N+P+K_2	2.93	188

*Yields and soil analyses represent the mean of three replicates. Crop planted 7-15-53, harvested 8-30-53.

**Second addition of the above rates of N, P and K were added prior to planting tomatoes. The first addition was made prior to planting the previous two crops, Soybeans and Black-eye cowpeas.

***Forage samples lost after harvest.

****Crop failure resulting from Red Spider damage.

L=Nitrogen, Eufaula — 4 Tons/A., Bowie — 4 Tons/A.

N=Nitrogen (50#/A. elemental N)

P=Phosphorus (200#/A. P_2O_5)

K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

characteristic pattern as to the relative amount of potassium that was extracted by neutral normal ammonium acetate.

Darnell sandy loam, freezing and thawing phase, is representative of this pattern, (Table 2). Considering the amount of potassium extracted at the end of the first cycle as a base, the amounts of potassium extracted from the end of the second cycle in ascending order calculated as pounds per acre of potassium were: hydrogen saturated 84, calcium saturated 358, untreated 434. An average of the amounts of potassium extracted from the end of the second cycle to the end of the eighth clcle shows no change of pattern but a change in amount, viz., hydrogen saturated 88, calcium saturated 379, and untreated 428 pounds per acre of potassium.

The maximum release of potassium was effected by the end of the fourth cycle in nearly all soils and treatments. A fixation of a portion of the released potassium occurred in most of these soils by the end of the fourth cycle.

Alternate freezing and thawing, or wetting and drying, resulted in similar release and/or fixation of potassium in all soils. Alternate wetting and drying resulted in a greater initial release of non-exchangeable potassium to the exchangeable form in most soils.

All soils exhibited a tendency to establish an equilibrium between their exchangeable and non-exchangeable potassium fractions. The average exchangeable potassium content of all soils at the end of the eighth cycle was lowest in the acid saturated soils, highest in the untreated

DARNELL and PARSONS—TOMATOES

Table 6.—The Effects of Various Fertilizer and Lime Additions on the Soil pH, Available Potassium Content and the Yield of Tomatoes in Greenhouse Experiments on Eufaula, Bowie and Darnell Soils.*

Treatments** (Unlimed)	Yield in Grams	Avail. K Lbs./A.	Treatments (Limed)	Yield in Grams	Avail. K Lbs./A.
		Darnell Sandy Loam			
Check	2.54	296	L	1.42	304
N+P	5.82	256	L+N+P	6.58	272
$N+P+K_1$	6.15	296	$L+N+P+K_1$	8.08	320
$N+P+K_2$	3.96	487	$L+N+P+K_2$	6.53	414
		Parsons Silt Loam			
Check	0.85	80	L	0.96	84
N+P	2.97	78	L+N+P	1.87	78
$N+P+K_1$	2.93	98	$L+N+P+K_1$	4.33	102
$N+P+K_2$	2.15	144	$L+N+P+K_2$	4.13	144

*Yields and soil analyses represent the mean of three replicates. Crop planted 7-15-53, harvested 8-30-53.

**Second addition of the above rates of N, P and K were added prior to planting tomatoes. The first addition was made prior to planting the previous two crops, Soybeans and Blackeye cowpeas.

L=Lime, Darnell – 2 Tons/A., Parsons – 4 Tons/A.

N=Nitrogen (50#/A. elemental N)

P=Phosphorus (200#/A. P_2O_5)

K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

soils, and intermediate for the calcium saturated soils. This held true for all soils and treatments except the Bowie soil, Table 2, freezing and thawing phase, which showed the same exchangeable potassium content in the calcium and untreated samples.

Considering the potassium extracted after the end of the first cycle as 100 percent, the hydrogen and calcium saturated soils were able to effect a greater percentage-wise release of potassium at the end of the second cycle from the non-exchangeable to the exchangeable form in most soils. Since all exchangeable potassium had been removed from the acid treated soils prior to incorporation into the study, movement of potassium as the soils approached an equilibrium would be from the non-exchangeable form to an available form. This trend was demonstrated for all soils in the wet and dry phase, likewise for the Bowie and Parsons soils in the freeze and thaw phase. (see Table 2). The Eufaula, Bowie, and Darnell soils in the freeze and thaw phase did not follow this pattern.

Microbiological activity throughout the incubation period was pronounced in all soils. Mold colonies were in evidence on the surface of the acid treated soils. Calcium saturated and untreated sandy soils developed a pleasant plowed-earth odor. Calcium saturated and untreated loam and silt loam soils developed a foul, unpleasant odor.

A fluctuation in the pH of all soils studied was noted. In most soils, an increase in available potassium content was accompanied by an increase in the soil pH. A fixation of potassium from the exchangeable form was accompanied by a decrease in the soil pH.

EUFAULA and BOWIE—OATS

Table 7.—The Effects of Various Fertilizer and Lime Additions on the Soil pH, Available Potassium Content and the Yield of Oats in Greenhouse Experiments on Eufaula and Bowie Soils.*

Treatments** (Unlimed)	Yield in Grams	Avail. K Lbs./A.	Treatments (Limed)	Yield in Grams	Avail. K Lbs./A.
		Eufaula Sand			
Check	1.4	26	L	1.7	19
N+P	1.4	30	L+N+P	1.4	25
N+P+K_1	1.9	103	L+N+P+K_1	2.6	109
N+P+K_2	4.3	126	L+N+P+K_2	2.4	123
		Bowie Sandy Loam			
Check	1.0	31	L	0.8	34
N+P	2.1	30	L+N+P	1.3	30
N+P+K_1	3.5	117	L+N+P+K_1	1.9	123
N+P+K_2	3.2	170	L+N+P+K_2	1.4	180

*Yields and soil analyses represent the mean of three replicates. Crop planted 9-20-53, harvested 10-29-53.

**Second addition of the above rates of N, P and K were added prior to planting tomatoes. The frist addition was made prior to planting the previous three crops, Soybeans, Blackeye cowpeas and tomatoes.

L=Lime, Eufaula — 4 Tons/A., Bowie — 4 Tons/A.

N=Nitrogen (50#/A. elemental N)

P=Phosphorus (200#/A. P_2O_5)

K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

Greenhouse Studies

Unlimed nitrogen and phosphorus fertilized pots produced lower yields of soybean forage than did the check pots in the Eufaula and Bowie series. The Darnell series did not follow this trend, in that the unlimed and limed nitrogen and phosphorus fertilized pots produced the highest yield of all treatments.

Limed pots of the Eufaula, Bowie, and Darnell series produced greater yields of soybean forage than did their unlimed counterparts with the exception of the Darnell series fertilized with potassium at the 200 pound per acre rate as shown in Table 3.

In general, blackeye cowpeas, tomatoes and oats grown on the limed pots of all soil series benefitted by the inclusion of potassium fertilizer. Though the pots that received potassium at the rate of 200 pounds per acre of K_2O showed a lower crop yield than those pots that received potassium at the rate of 100 pounds per acre in nine of the fourteen treatments where these combinations were used, in no instance was the forage yield as low as that recorded for the pots that received lime alone.

Analyses of soybean and blackeye cowpea forage for potassium, sodium, calcium, magnesium, phosphorus and nitrogen as shown in Tables 9 through 11 gave the following results.

DARNELL and PARSONS—OATS

Table 8.—The Effects of Various Fertilizer and Lime Additions on the Soil pH, Available Potassium Content and the Yield of Oats in Greenhouse Experiments on Darnell and Parsons Soils.*

Treatments** (Unlimed)	Yield in Grams	Avail. K Lbs./A.	Treatments (Limed)	Yield in Grams	Avail. K Lbs./A.
		Darnell Sandy Loam			
Check	2.7	212	L	3.3	223
N+P	4.5	105	L+N+P	2.1	212
$N+P+K_1$	3.7	198	$L+N+P+K_1$	4.3	189
$N+P+K_2$	4.2	233	$L+N+P+K_2$	4.3	275
		Parsons Silt Loam			
Check	2.3	94	L	1.6	89
N+P	3.1	61	L+N+P	2.9	82
$N+P+K_1$	4.7	101	$L+N+P+K_1$	4.1	95
$N+P+K_2$	4.8	112	$L+N+P+K_2$	5.7	106

*Yields and soil analyses represent the mean of three replicates. Crop planted 9-20-53, harvested 10-29-53.

**Second addition of the above rates of N, P and K were added prior to planting tomatoes. The frist addition was made prior to planting the previous three crops, Soybeans, Blackeye cowpeas and tomatoes.

L=Lime, Darnell – 2 Tons/A., Parsons – 4 Tons/A.

N=Nitrogen (50#/A. elemental N)

P=Phosphorus (200#/A. P_2O_5)

K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

The percentage of potassium increased in all plants with increased potassium application to the soil.

The potassium content was lower in the limed treatments than in the unlimed.

The percentage of sodium decreased in practically all plants with increased potassium application to the soil. Sodium content was higher in the limed treatments as compared to corresponding unlimed treatments.

The percentage of calcium decreased with increased potassium application to the soil. Calcium content was higher in the limed treatments.

The percentage of magnesium decreased with increased potassium application to the soil. Plants on unlimed soils had higher magnesium contents than those grown on the limed soils.

The percentage of phosphorus was highest in the plants grown on both untreated and limed soils where potassium fertilizer was not included.

The percentage of nitrogen decreased slightly in some plants with increased potassium application to the soil.

Table 9.—The Effect of Various Fertilizer and Lime Additions on the Potassium, Sodium, Calcium, Magnesium, Phosphorus and Nitrogen Content of Soybean and Blackeye Cowpea Forage Grown in Eufaula Sand in the Grenhouse Experiment.*

Soil Treatments**	% K	% Na	% Ca	% Mg	% P	% N	Yield in Grams
			Soybean Forage				
Check	1.40	0.04	0.80	0.73	0.14	3.21	1.23
N+P	1.23	0.04	1.68	0.57	0.41	3.32	1.10
N+P+K_1	1.63	0.07	1.28	0.57	0.40	4.22	1.00
N+P+K_2	2.93	0.04	1.52	0.58	0.40	4.22	1.50
L	1.10	0.03	1.28	0.22	0.14	2.60	1.66
L+N+P	1.07	0.03	1.52	0.33	0.32	3.15	2.30
L+N+P+K_1	2.80	0.08	1.68	0.15	0.27	4.29	2.70
L+N+P+K_2	3.13	0.03	1.20	0.09	0.28	2.49	2.57
			Blackeye Cowpea Forage				
Check	2.33	0.19	1.12	0.85	0.19	3.15	3.3
N+P	***						
N+P+K_1	***						
N+P+K_2	***						
L	1.67	0.17	2.56	0.67	0.15	3.28	2.57
L+N+P	1.33	0.15	2.56	0.60	0.43	3.19	3.17
L+N+P+K_1	2.73	0.12	1.92	0.40	0.38	2.94	4.73
L+N+P+K_2	3.00	0.11	2.16	0.40	0.38	2.49	4.50

*All forage analyses performed in duplicate.
**Check — No treatment, L = Lime (4 Tons/A.)
N=Nitrogen (50#/A. elemental N)
P=Phosphorus (200#/A. P_2O_5)
K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)
***Crop failure.

Table 10.—The Effect of Various Fertilizer and Lime Additions on the Potassium, Sodium, Calcium, Magnesium, Phosphorus and Nitrogen Content of Soybean and Blackeye Cowpea Forage Grown in Bowie Sandy Loam in the Greenhouse Experiment.*

Soil Treatments**	% K	% Na	% Ca	% Mg	% P	% N	Yield in Grams
			Soybean Forage				
Check	2.87	0.04	0.56	0.58	0.12	2.41	3.07
N+P	2.33	0.03	1.12	0.97	0.40	3.52	2.73
$N+P+K_1$	2.80	0.04	0.56	0.60	0.38	2.94	2.93
$N+P+K_2$	3.64	0.03	0.48	0.48	0.37	3.44	3.10
L	1.37	0.04	0.88	0.42	0.13	2.49	3.90
L+N+P	1.17	0.07	1.04	0.55	0.12	2.95	4.60
$L+N+P+K_1$	2.23	0.03	1.04	0.42	0.13	2.88	4.07
$L+N+P+K_2$	2.87	0.04	1.12	0.40	0.14	2.88	3.47
			Blackeye Cowpea Forage				
Check	1.47	0.12	1.12	0.80	0.22	3.14	4.47
N+P	1.63	0.16	0.96	1.07	0.45	3.35	5.30
$N+P+K_1$	2.60	0.13	0.96	0.80	0.33	3.13	5.13
$N+P+K_2$	3.20	0.12	0.88	0.77	0.37	2.87	5.47
L	1.67	0.15	2.00	0.43	0.17	2.97	4.23
L+N+P	1.57	0.17	2.16	0.73	0.33	3.16	4.00
$L+N+P+K_1$	1.93	0.12	2.48	0.57	0.31	2.85	4.97
$L+N+P+K_2$	3.27	0.13	2.32	0.55	0.29	2.95	4.60

*All forage analyses performed in duplicate.
**Check — No treatment, L = Lime (2 Tons/A.)
N=Nitrogen (50#/A. elemental N)
P=Phosphorus (200#/A. P_2O_5)
K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

Table 11.—The Effect of Various Fertilizer and Lime Additions on the Potassium, Sodium, Calcium, Magnesium, Phosphorus and Nitrogen Content of Soybean and Blackeye Cowpea Forage Grown in Darnell Sandy Loam Soil in the Greenhouse Experiment.*

Soil Treatments**	% K	% Na	% Ca	% Mg	% P	% N	Yield in Grams
			Soybean Forage				
Check	3.07	0.09	0.88	0.58	0.15	2.71	4.93
N+P	3.20	0.03	0.96	0.60	0.45	3.05	7.07
$N+P+K_1$	3.51	0.07	0.96	0.58	0.16	3.10	6.47
$N+P+K_2$	3.39	0.04	0.88	0.52	0.19	3.07	6.73
L	3.00	0.04	0.96	0.53	0.12	3.08	5.03
L+N+P	2.87	0.03	1.12	0.58	0.18	2.74	7.30
$L+N+P+K_1$	3.20	0.03	0.96	0.48	0.16	2.87	6.63
$L+N+P+K_2$	3.39	0.03	0.88	0.45	0.14	2.87	6.67
			Blackeye Cowpea Forage				
Check	3.51	0.12	1.92	0.90	0.16	3.33	4.03
N+P	3.45	0.15	1.92	1.03	0.21	3.05	3.30
$N+P+K_1$	3.69	0.07	1.60	1.10	0.21	3.23	5.10
$N+P+K_2$	3.39	0.09	2.08	0.88	0.32	3.17	4.17
L	3.45	0.13	2.16	0.78	0.19	3.35	2.03
L+N+P	3.20	0.07	2.32	0.93	0.26	3.56	3.67
$L+N+P+K_1$	3.39	0.07	2.16	0.88	0.23	3.24	3.97
$L+N+P+K_2$	3.51	0.07	2.32	0.80	0.25	3.42	4.53

*All forage analyses performed in duplicate.
**Check — No treatment, L = Lime (2 Tons/A.)
N=Nitrogen (50#/A. elemental N)
P=Phosphorus (200#/A. P_2O_5)
K=Potassium K_1 (100#/A. K_2O) K_2 (200#/A. K_2O)

Summary

Alternate freezing and thawing or alternate wetting and drying gave similar results on the release and/or fixation of potassium in all soils and treatments. All soils released a portion of their fixed potassium to the exchangeable form, then fixed a portion of that released by the end of the fourth cycle. A dynamic equilibrium between the fixed and exchangeable fractions of potassium functioned in all soils studied.

Alternate wetting and drying resulted in a greater initial release of non-exchangeable potassium to the exchangeable form in all soils and chemical treatments, except for the untreated Bowie soil. Calcium increased potassium fixation in soils in a form not extractable with neutral normal ammonium acetate.

The pH of all soils fluctuated during physical treatments, generally increasing with potassium release and decreasing with potassium fixation. The greenhouse experiments demonstrated the need for considering the balance of available forms of nitrogen, phosphorus and potassium in relation to each other as well as the amounts of these elements in a soil.

Improved soil management practices, including the increased use of irrigation and the use of higher analysis fertilizers with higher rates of fertilization, require more precise information concerning soil factors influencing crop response to potassium fertilization.

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