THE EFFECT OF POTASSIUM FERTILIZATION ON THE GROWTH AND CHEMICAL COMPOSITION OF GRASSES AND LEGUMES GROWN ON SOILS LOW AND VERY LOW IN EXCHANGABLE POTASSIUM.

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INTRODUCTION

Recent studies in eastern Oklahoma have shown that a lack of exchangable soil potassium is, in many cases, a limiting factor in crop production. Test plots in eastern Oklahoma have shown that some legumes and grain crops have a much higher potassium requirement than others. Consequently variations in the exchangable potassium of a soil is only one factor which may affect the response of a crop to potassium fertilization.

When the exchangable potassium of a soil is very low and other plant nutrients are not limiting factors in plant development characteristic physical symptoms of potassium deficiency will appear on the leaves of many crops. On many soils a marked response from potassium fertilization is obtained where plant deficiency symptoms do not appear; indicating that a deficiency of exchangable potassium great enough to reduce yields can occur without being detected by plant symptoms.

At the present time very little accurate information is available showing the relationship between exchangable potassium in soil and the growth and response of plants to potassium fertilization. The correlation between exchangable potassium content of soils with response of plants to potassium fertilization appears to be a soil type problem and does not follow simple arithmetic values.

The purpose of this investigation is to study the effect of potassium fertilizers and soil on the chemical composition of grasses and legumes and, if possible, determine which of those plants studied have the highest and lowest potassium requirements, and which ones produce the greatest increase in yield of forage for a given fertilizer treatment on a given soil.

REVIEW OF THE LITERATURE

As early as 1756 Homes in Scotland noticed that plants responded to potassium fertilization (30).

Jones (14) states that alfalfa is a tremendously heavy feeder on potassium, pointing out that a soil producing 1.69 tons of hay per acre will lose 45 pounds of K_2O per acre while 16.6 bushels of soybean seed would decrease the K_2O content 15.8 pounds per acre.

Bear et al, (5) (6) (7) have reached the conclusion that the critical lower limit for the optimum production of alfalfa is between 60 and 80 pounds of exchangable potassium per million pounds of soil.

Winters (32) reports that soils should contain 160 pounds of exchangable potassium per acre to produce 90 percent of the maximum yield of alfalfa.

Munsell (17) recommends that an application of 200 pounds of 60 percent KCl annually should be applied to alfalfa grown on Connecticut soils.

Chandler et al (8) state that when the potassium content of alfalfa was below 1.25 percent the majority of stands showed a yield response greater than 20 percent and when the potassium content was about 1.25 percent the yield response was less than 20 percent.

Snider (25) points out that alfalfa hay increased in potassium content when potassium was added to soils containing 60 to 100 pounds per acre of exchangable potassium.

Chandler et al (8) checked 57 soils that contained less than 80 pounds per acre of exchangable potassium and 44 of them showed yield responses in excess of 20 percent.

Ensminger (11) found that lespedeza responded to potassium fertilization when grown on a Leon fine sand containing 60 pounds of exchangable potassium per acre, but to a lesser extent than White Dutch clover which showed a 300 percent increase in forage production compared to 20 percent for lespedeza.

Ginsburg (12) reported that soybeans suffering from potash deficiency develop very few lateral roots. This finding is confirmed by Eckstein, Bruno, and Turrentine (10).

Albrecht et al (1) state that potassium fertilization on Putnam silt loam raises the concentration of nitrogen in sweet clover and presumably increases nitrogen fixation. McTaggart (16) concluded that potassium fertilization exerted its greatest influence in increasing the nitrogen content of Canada field peas and alfalfa and in decreasing the nitrogen content of soybeans. McTaggart's work was conducted in sand cultures.

Nelson and Caldwell (19) reported that soybeans responded to potassium fertilization when grown on a very low potassium Norfolk loamy sand which was fertilized with 36 pounds of K_2O per acre. Viltum and Mulvey (29) report the same results when a Crosby silt loam was fertilized with 400 pounds per acre of 0-10-20.

Drake and Scarseth (9) have shown that alfalfa and sweet clover can utilize about 65 and 80 percent of the exchangable soil potassium respectively on Crosby silt loam soil. They also point out that the response of crops to potassium fertilization was entirely different from the ability of the crop to absorb potassium from a less available form. Crops that can use less of the exchangable potassium in a soil will give the greatest response to potassium fertilization. The response of plants to potassium fertilization was almost inversely proportional to the abilities of the plant to absorb exchangable potassium from the soil.

Snider (26) states that in many cases sweet clover yields can be doubled by potassium fertilization when grown on light colored Illinois soils containing approximately 80 pounds per acre of exchangable potassium. Snider (26) also states that sweet clover tops and roots in the spring of the second season's growth, had a considerable increase in potassium content due to potash treatment. Lespedeza, vetch, and soybeans also showed a marked increase in total potassium content when potassium was applied to soils containing eighty pounds of exchangable potassium per acre.

Murphy (18) points out that in order to get a crop response from potassium fertilization in most cases it is necessary to supply phosphorus as well.

Baver (4) states that grasses seem to show the least response to potassium fertilization

EXPERIMENTAL PROCEDURE

Source and Composition of Soils

The two soils used in this study were obtained from different areas in Oklahoma. Both were cultivated soils with a low to very low exchangable potassium content.

Bates loam and Bowie very fine sandy loam were chosen for the experiment. Bates loam is a prairie type soil and developed under grass vegetation. Bowie very fine sandy loam is a coastal plains soil, and developed under timber. The Bates soil was obtained from an area near Chelsea, Oklahoma in Rogers County and the Bowie soil was obtained from an area near Atoka, Oklahoma in Atoka County.

Both soils were very low in fertility. The Bowie soil contained 38 pounds per acre of exchangable potassium, 0.39 percent organic matter, and 16.0 pounds of easily soluble phosphorus per acre. The soil reaction was moderately acid. The Bates soil contained 82.2 pounds per acre of exchangable potassium, 1.9 percent organic matter, and 6.4 pounds of easily soluble phosphorus per acre by the acetic acid method (13). The soil reaction was moderately acid.

Plan of Greenhouse Experiment

The two soils used in this experiment were screened through a four-mesh sieve and weighed into two and one-half gallon glazed pots. Each pot of the Bowie series contained twenty-six pounds of soil which was covered with one pound of coarse silica sand. Each pot of the Bates series contained nineteen pounds of soil which was covered with one pound of coarse silica sand. The silica sand was used to cover the surface of each pot of soil to prevent puddling by the periodic addition of water.

Ten crops - Rye grass, brome grass, Ladino clover, crimson clover, alfalfa, hairy vetch, hubam sweet clover, Korean lespedeza, soybeans, and big hop clover were planted and fertilized in the winter of 1948. In each case the number of pots per crop was five; each series consisting of one limed pot of soil, duplicates of lime, nitrogen, and phosphorus, and of lime, nitrogen, phosphorus, and potassium.

The rate of fertilization was 300 pounds of 20 percent superphosphate per acre on all pots which received phosphorus. The grasses received ammonium sulfate at the rate of two hundred pounds per acre. The legumes received ammonium sulfate at the rate of one hundred pounds per acre. Each of the potassium fertilized pots received two hundred pounds per acre of potassium chloride. Finely ground limestone necessary to correct soil acidity was added to each pot.

At the beginning of the experiment each pot was assigned a specific weight. The weight was determined by weighing the pot plus the weight of soil, sand, and a volume of water required to bring the soil moisture up to 75 percent of field capacity. At regular intervals throughout the experiment the original weight of each pot of soil was restored by the addition of distilled water. These intervals were weekly at first, but as the plants grew and water requirements increased the plants were watered twice a week. At each watering the pots were rotated in such a manner as to have all of them subjected to as nearly identical light conditions as possible.

Each crop was harvested for chemical analysis as soon as it appeared to be nearing maturity. Analyses were made for total nitrogen, phosphorus, potassium, and calcium. The magnesium content of crops on the Bowie soil also was determined.

Methods of Chemical Analysis

NITROGEN -- Organic and ammonia nitrogen was determined by the method recommended by the Association of Official Agricultural Chemists (3) with the exception that selenium was added as a catylst instead of copper, or mercury, and sodium sulfate was added to the digestion flask to raise the boiling point.

PHOSPHORUS -- Total phosphorus was determined by the colorimetric molybdenum blue method suggested by Shelton and Harper (24) for the analysis of forage and grain.

MAGNESIUM -- Magnesium was determined by precipitating with 8-hydroxyquinoline, a method proposed by Alexander and Harper (2) for the determination of magnesium in soils and modified by Harper (13) for the determination of magnesium in plant material.

POTASSIUM -- This element was determined by the perchlorate method as recorded by Tredwell and Hall (27) with modifications by Harper (13) especially for plant material.

CALCIUM -- Calcium was determined by the official method of the Association of Official Agricultural Chemists (3) with the exception that the initial aliquot was neutralized to the end point of brome cresol green with ammonium hydroxide (pH 4.6 - 4.8) and buffered with a sodium acetate-acetic acid buffer solution. Acetic acid is desirable in the solution as it is well known that calcium oxalate is insoluble in acetic acid and that iron and aluminum are not precipitated from such a solution, therefore, calcium precipitated from solutions containing other metallic salts is generally obtained in a purer form (31).

EXPERIMENTAL RESULTS AND DISCUSSION.

Data on the Bowie Soil

The yield of grasses and legumes produced in greenhouse pots filled with Bowie very fine sandy loam and receiving different fertilizer treatments are given in Tables 1 and 2. The growth of brome and rye grass on the limed pots was very low. Lime, nitrogen, and phosphorus increased the yields approximately 200 percent over the limed pots. An addition of potassium to the soil with nitrogen, phosphorus, and lime produced a 12.98 percent increase in forage yield of brome grass and a 15.36 percent increase in forage yield of rye grass. The second cutting of both grasses showed that the potassium applied increased the forage production of brome grass 24.18 percent while the rye grass yield was decreased 4.70 percent. These figures indicate that potassium is probably necessary for a sustained yield of brome grass. Observation of the brome grass after the first clipping indicated that those plants growing on the potassium fertilized soil made a more rapid recovery and faster growth than those plants growing on soil that had not received potassium. Observations and yield data of the rye grass indicate that this crop will respond to potassium fertilization when grown on a soil very low in exchangable potassium after lime, nitrogen, and phosphorus have been added. The second cutting of rye grass did not benefit from potassium fertilization. This was probably due to a further decrease of other elements that were not added by fertilization.

Yields of legumes on the Bowie soil were not too high and in many cases erratic. Big hop clover, crimson clover, and alfalfa gave the best response to potassium fertilization. Big hop clover presented an interesting problem in that the only plants that grew and developed were those that had been fertilized with potassium. Crimson clover showed a 24.44

TABLE 1. Yield of Grasses Grown in Pots on Bowie Very Fine Sandy Loam with Different Fertilizer Treatments.

Crop	Air Dry Forage Per Pot in Grams		Air Dry Forage Per Acre in Pounds		Average Pounds Per Acre		% Forage Increase Due to Potassium Applied.	
	1st Cutting	2nd Cutting	1st Cutting	2nd Cutting	1st Cutting	2nd Cutting	1st Cutting	2nd Cutting
Brome grass*	3.5	2.9	713	606				
Brome grass**	9.9	4.8	2017	978				
Brome grass**	9.3	4.3	1894	876	1956	927		
Brome grass***	10.9	5.6	2220	1141				
Brome grass***	10.8	5.7	2199	1161	2209	1151	12.98	24.18
Rye grass*	1.91	2.5	389	509				
Rye grass**	4.56	5.1	929	1039				
Rye grass**	4.93	5.5	1004	1120	967	1080		
Rye grass***	5.77	5.1	1175	1039				
Rye grass***	5.40	5.0	1055	1019	1115	1029	15.36	-4.7

* Soil received 1.5 tons of lime per acre.

** Soil received 1.5 tons of lime, 300 pounds of superphosphate, and 200 pounds of $(NH_4)_2\ SO_4$ per acre.

*** Soil received 1.5 tons of lime, 300 pounds of superphosphate, 200 pounds of $(NH_4)_2\ SO_4$, and 200 pounds of KCl per acre.

TABLE 2. Yield of Legumes Grown in Pots on Bowie Very Fine Sandy Loam with Different Fertilizer Treatments.

Crop	Air Dry Forage Per Pot in Grams	Air Dry Forage Per Acre in Pounds	Average Pounds Per Acre	% Forage Increase due to Potassium Applied
Ladino*	3.7	754		
Ladino**	4.5	917		
Ladino**	4.95	1008	963	
Ladino***	4.3	876		
Ladino***	5.8	1182	1029	6.88
Big Hop*	---*	---*		
Big Hop**	---*	---*		
Big Hop**	---*	---*	---*	
Big Hop***	5.7	1161		
Big Hop***	4.0	815	988	100
Crimson*	3.5	713		
Crimson**	4.3	876		
Crimson**	4.7	957	917	
Crimson***	5.6	1141		
Crimson***	---*	---*	1141	24.44
Alfalfa*	4.9	998		
Alfalfa**	4.7	957		
Alfalfa**	4.7	957	957	
Alfalfa***	5.4	1100		
Alfalfa***	5.5	1120	1110	15.96
Sweet Clover*	8.3	1691		
Sweet Clover**	10.0	2037		
Sweet Clover**	11.9	2424	2231	
Sweet Clover***	12.0	2445		
Sweet Clover***	9.8	1996	2221	-.456
Lespedeza*	6.2	1263		
Lespedeza**	8.3	1691		
Lespedeza**	7.5	1528	1609	
Lespedeza***	7.45	1518		
Lespedeza***	7.20	1467	1492	-7.28

* Soil received 1.5 tons of lime per acre.

** Soil received 1.5 tons of lime, 300 pounds of superphosphate, and 100 pounds of $(NH_4)_2\ SO_4$ per acre.

*** Soil received 1.5 tons of lime, 300 pounds of superphosphate, 100 pounds of $(NH_4)_2\ SO_4$, and 200 pounds of KCl per acre.

---* Seeds germinated but plants failed to grow.

percent increase in forage production due to potassium applied. Alfalfa and Ladino clover responded with a 15.86 and 6.88 percent increase, respectively. Sweet clover and lespedeza, the crops that did not respond to potassium fertilization, grew best on the Bowie soil. Both appeared healthy and produced more forage than any of the other legumes. The only visible effect potassium had upon these two crops was the development of larger and stronger stems. Nelson et al (20) and Pague (22) report that potassium aids in developing stronger, healthier stems. The negative results indicate that phosphorus was the deciding factor and that when the potassium content of the plants increased the yield response decreased. Ulrich (28) has recorded similar results while working at various fertility levels with Ladino clover.

Soybeans and vetch were originally included in this experiment but both were excessively damaged by red spider infestation, therefore, yield data were not reported.

The low yields and poor appearance of the legumes grown on the Bowie soil indicate that one or more plant nutrients, other than those added, were deficient. The leaves of Ladino clover and big hop clover had a white-green appearance dotted with chlorotic spots. Crimson clover developed a pale red color in the leaves and stems early in growth and this condition remained until the plants were harvested. The leaves of alfalfa often appeared yellowish or pale green with chlorotic spotting. Further work, probably with minor elements, would be required before an explanation of these observations could be made.

Data on the chemical analyses of the grasses grown on Bowie very fine sandy loam are given in Table 3. These results show that a definite pattern was established in the potassium content of each crop. In every case plants fertilized with nitrogen and phosphorus had a lower potassium

TABLE 3. Chemical Composition of Grasses Grown in Pots on Bowie Very Fine Sandy Loam with Different Fertilizer Treatments.

Crop	Percent Potassium		Percent Phosphorus		Percent Calcium		Percent Magnesium		Percent Nitrogen	
	1st Cut-ting	2nd Cut-ting	1st Cut-ting	2nd Cut-ting	1st Cut-ting	2nd Cut-ting	1st Cut-ting	2nd Cut-ting	1st Cut-ting	2nd Cut-ting
Brome grass*	3.27	1.84	.17	.27	1.14	1.15	.52	.25	1.27	1.13
Brome grass**	1.23	1.52	.14	.23	1.15	1.34	.56	.25	1.31	1.11
Brome grass**	1.27	1.51	.15	.28	1.18	1.39	.59	.28	1.36	1.36
Brome grass***	3.22	2.17	.14	.24	.93	1.21	.29	.19	1.22	.98
Brome grass***	2.84	2.02	.13	.23	.92	1.21	.28	.21	1.18	.97
Rye grass*	3.52	2.13	.29	.24	1.52	1.49	.43	.50	---*	---*
Rye grass**	2.37	1.61	.26	.23	1.90	1.69	.45	.43	2.71	.85
Rye grass**	2.12	1.51	.28	.23	1.78	1.51	.43	.39	2.52	.81
Rye grass***	4.44	1.76	.28	.26	1.32	1.33	.32	.32	2.10	.81
Rye grass***	4.47	1.81	.29	.27	1.24	1.35	.31	.37	2.19	.73

* Soil received 1.5 tons of lime per acre

** Soil received 1.5 tons of lime, 300 pounds of superphosphate, and 200 pounds of $(NH_4)_2SO_4$ per acre.

*** Soil received 1.5 tons of lime, 300 pounds of superphosphate, 200 pounds of $(NH_4)_2SO_4$, and 200 pounds of KCl per acre.

---* Not enough sample for analysis.

content than those plants that received lime alone. In this case the total potassium content of the plant was diluted by the increase in growth brought about by phosphorus and nitrogen. The addition of lime, nitrogen, phosphorus, and potassium again increased the potassium content of the grasses to a point comparable to the percentage obtained when only lime was added.

The potassium percentages as recorded for rye grass in Table 3 probably approaches a maximum. These figures indicate that the plant takes up large amounts of easily available potassium. Potassium percentages comparable to those found here have been recorded by Jones (15). Comparable figures for the potassium content of brome grass may be found as recorded by Price et al (23).

Potassium fertilization did not have any appreciable effect upon the phosphorus content of brome grass or rye grass. There is, however, a slight indication that as the potassium content of rye grass goes down the phosphorus content goes down also. Calcium and magnesium decreased as the potassium increased.

A comparison of the nitrogen content of the two grasses indicates that potassium fertilization tends to lower the nitrogen content.

The chemical analyses of legumes grown on the Bowie soil are presented in Table 4. In every case potassium fertilization increased the potassium content of each of the legumes, but had very little effect upon the phosphorus content. Crimson clover was the only crop that showed a reduction in phosphorus percentage due to potassium fertilization. An increase in the potassium content caused a reduction in the uptake of both calcium and magnesium. It should be pointed out at this point that in every case there is an unbalanced condition in the calcium-magnesium ratio of the legumes. The normal ratio is approximately 3 to 1. In the

TABLE 4. Chemical Composition of Legumes Grown in Pots on Bowie Very Fine Sandy Loam with Different Fertilizer Treatments.

Crop	Percent Potassium	Percent Phosphorus	Percent Calcium	Percent Magnesium	Percent Nitrogen
Ladino*	1.77	.21	2.41	.52	xxxx
Ladino**	1.38	.21	2.62	.53	xxxx
Ladino**	1.53	.24	2.32	.50	xxxx
Ladino***	2.34	.24	1.95	.37	xxxx
Ladino***	2.77	.22	2.03	.42	xxxx
Big Hop*	---*	---*	---*	---*	---*
Big Hop**	---*	---*	---*	---*	---*
Big Hop**	---*	---*	---*	---*	---*
Big Hop***	2.64	.24	1.91	.36	1.60
Big Hop***	2.70	.24	2.10	.38	1.67
Crimson*	2.15	.34	2.52	.57	xxxx
Crimson**	2.38	.35	2.54	.62	xxxx
Crimson**	2.05	.30	2.32	.70	xxxx
Crimson***	2.83	.26	2.19	.47	xxxx
Crimson***	3.13	.26	3.28	.34	xxxx
Alfalfa*	1.23	.22	2.11	.47	2.16
Alfalfa**	1.12	.23	2.13	.48	2.24
Alfalfa**	1.25	.23	2.12	.48	2.18
Alfalfa***	2.22	.23	1.97	.35	2.35
Alfalfa***	2.26	.24	1.85	.36	2.26
Sweet Clover*	.95	.12	2.04	.51	2.15
Sweet Clover**	1.04	.20	1.64	.41	2.54
Sweet Clover**	.98	.17	2.00	.47	2.20
Sweet Clover***	2.10	.18	1.34	.35	2.49
Sweet Clover***	1.68	.17	1.61	.38	2.08
Lespedeza*	.77	.21	1.64	.33	1.30
Lespedeza**	.87	.23	1.80	.38	1.90
Lespedeza**	.90	.24	2.05	.42	1.81
Lespedeza***	1.05	.25	1.97	.39	2.03
Lespedeza***	1.04	.23	2.08	.38	1.99

* Soil received 1.5 tons of lime per acre.

** Soil received 1.5 tons of lime, 300 pounds of superphosphate, and 100 pounds of $(NH_4)_2SO_4$ per acre.

*** Soil received 1.5 tons of lime, 300 pounds of superphosphate, 100 pounds of $(NH_4)_2SO_4$, and 200 pounds of KCl per acre.

---* Seeds germinated but plants failed to grow.

xxxx Not enough sample for analysis.

case of the plants grown on the Bowie soil the magnesium content was very low, indicating that magnesium is deficient and probably one of the limiting factors in crop production on this soil.

A comparison of the effect of potassium upon the nitrogen content of legumes grown on the Bowie soil cannot be made as insufficient forage was obtained for a nitrogen determination on Ladino and crimson clover. The only big hop clover plants were in those pots receiving potassium fertilization. Potassium fertilization had a tendency to increase the nitrogen content of alfalfa and lespedeza.

Data on the Bates Soil.

Yields of brome and rye grass produced on Bates loam are given in Table 5. Lime, nitrogen, and phosphorus produced much higher yields than lime alone. When potassium was added with lime, nitrogen, and phosphorus the first cutting of brome and rye grass responded with a 17.41 percent increase and 10.47 percent increase respectively in forage yield. The second cutting of both grasses showed that potassium increased the forage production of brome grass 5.77 percent while the rye grass yield was increased 26.89 percent. This indicates that not enough potassium was added to maintain a high yield of brome grass. There was still sufficient plant food, however, for rye grass to continue growing vigorously, tiller, and produce an increase in forage over the first cutting. A comparison of the two grasses bears out the fact that rye grass has a lower fertility requirement than brome grass.

Yields of legumes on the Bates soil are given in Table 6. These yields with the exception of Ladino clover were satisfactory. The stand of Ladino clover was not uniform, therefore, data from this crop were not

TABLE 5. Yield of Grasses Grown in Pots on Bates Loam with Different Fertilizer Treatments.

Crop	Air Dry Forage Per Pot in Grams		Air Dry Forage Per Acre in Pounds		Average Pounds Per Acre		% Forage Increase Due to Potassium Applied	
	1st cutting	2nd cutting	1st cutting	2nd cutting	1st cutting	2nd cutting	1st cutting	2nd cutting
Brome grass*	8.2	7.2	1670	1467				
Brome grass**	13.3	10.15	2709	2068				
Brome grass**	14.8	9.60	3015	1956	2862	2012		
Brome grass***	16.0	11.10	4011	2261				
Brome grass***	13.3	9.79	2709	1994	3360	2128	17.41	5.77
Rye grass*	2.84	15.0	579	3056				
Rye grass**	7.0	13.0	1426	2648				
Rye grass**	8.2	17.5	1670	3565	1548	3007		
Rye grass***	8.46	19.2	1723	3911				
Rye grass***	8.33	19.5	1697	3972	1710	3942	10.47	26.89

* Soil received two tons of lime per acre.

** Soil received two tons of lime, 300 pounds of superphosphate, and 200 pounds of $(NH_4)_2 SO_4$ per acre.

*** Soil received two tons of lime, 300 pounds of superphosphate, 200 pounds of $(NH_4)_2 SO_4$, and 200 pounds of KCl per acre.

included in this discussion. Big hop clover produced the greatest response to potassium fertilization, showing a 33.5 percent increase due to the potassium applied. A comparison of the yield response of big hop clover due to potassium fertilization on the two soils tends to establish the fact that this plant will not produce satisfactorily until its potassium requirement is satisfied. Soybeans responded to potassium fertilization, producing a 23.73 percent increase in forage yield. Those soybean plants that were fertilized with potassium were taller, had larger stems and were more vigorous and healthy in appearance than similar plants on the pots fertilized with lime, nitrogen, and phosphorus. It is believed, however, that two hundred pounds of potassium chloride per acre on this soil was not enough for soybeans as mild potash deficiency symptoms on the leaves of the soybean plants were observed.

Crop responses to potassium fertilization were as follows: Lespedeza 12.58 percent, crimson clover 12.13 percent, alfalfa 11.13 percent, vetch 6.25 percent, and sweet clover 1.19 percent. The increase in lespedeza production indicates that even though lespedeza is adapted to and will produce a fair yield on very low fertility soils it will respond to good treatment. The stand of crimson clover was good in all pots, but there was very little difference in height between those plants on the soils receiving lime, nitrogen, and phosphorus and those receiving lime, nitrogen, phosphorus, and potassium. Nevertheless, potassium fertilization increased the yield by approximately one thousand pounds per acre. Alfalfa did not grow too well on the Bates soil and the appearance of the plants indicated that other plant nutrients were limiting development other than those applied. Vetch gave very little response to potassium, but responded to lime, nitrogen, and phosphorus. Lime and phosphorus requirements should be considered first when growing vetch, and potassium should be applied

TABLE 6. Yield of Legumes Grown in Pots on Bates Loam with Different Fertilizer Treatments.

Crop	Air Dry Forage Per Pot in Grams	Air Dry Forage Per Acre in Pounds	Average Pounds Per Acre	% Forage Increase due to Potassium Applied
Big Hop*	10.7	2180		
Big Hop**	18.9	3850		
Big Hop**	17.3	3524	3687	
Big Hop***	24.55	5001		
Big Hop***	23.80	4848	4925	33.56
Crimson*	10.6	2159		
Crimson**	23.1	4706		
Crimson**	22.65	4614	4660	
Crimson***	26.20	5337		
Crimson***	25.10	5113	5225	12.13
Alfalfa*	8.0	1630		
Alfalfa**	14.9	3035		
Alfalfa**	15.3	3117	3076	
Alfalfa***	18.15	3697		
Alfalfa***	15.41	3139	3418	11.13
Soybeans*	15.76	3210		
Soybeans**	20.80	4237		
Soybeans**	24.30	4950	4593	
Soybeans***	28.20	5745		
Soybeans***	27.60	5622	5683	23.73
Sweet Clover*	5.10	1039		
Sweet Clover**	13.20	2689		
Sweet Clover**	12.10	2465	2577	
Sweet Clover***	12.60	2567		
Sweet Clover***	13.00	2648	2607	1.19
Vetch*	5.9	1202		
Vetch**	18.7	3810		
Vetch**	16.6	3382	3596	
Vetch***	19.5	3972		
Vetch***	18.1	3687	3830	6.25
Lespedeza*	8.6	1752		
Lespedeza**	13.8	2811		
Lespedeza**	15.6	3178	2995	
Lespedeza***	16.7	3402		
Lespedeza***	16.4	3341	3372	12.58

* Soil received two tons of lime per acre.

** Soil received two tons of lime, 300 pounds of superphosphate, and 100 pounds of $(NH_4)_2 SO_4$ per acre.

*** Soil received two tons of lime, 300 pounds of superphosphate, 100 pounds of $(NH_4)_2 SO_4$, and 200 pounds of KCl per acre.

to those soils that are very low in exchangable potassium. Sweet clover did not respond to potassium fertilization indicating that it has a strong foraging power for potassium which does not exist in an exchangable form.

The chemical analyses of the grasses grown on the Bates soil are given in Table 7. These results show the same potassium pattern as those grown on the Bowie soil. Potassium fertilization increased the potassium content of each of the grasses. The phosphorus content was not appreciably changed by an increase in the potassium content of the plant, however, there was a tendency for the phosphorus content to drop slightly. The calcium content decreased as the potassium increased. Nitrogen was not constant in the grasses. The nitrogen content of brome grass decreased while the nitrogen content of rye grass increased slightly due to the potassium applied.

The chemical analyses of legumes grown on Bates soil are presented in Table 8. In every case potassium fertilization increased the potassium content of each legume. The phosphorus content of big hop, crimson, sweet clover, and soybeans was lowered slightly while the phosphorus content of alfalfa, vetch, and lespedeza was slightly higher than the limed soil. A comparison of the calcium analyses shows that the calcium content of the legumes decreased as the potassium increased with the exception of lespedeza and alfalfa, both of which exhibited a slight calcium increase. The effect of potassium fertilization upon the nitrogen content of legumes is very obscure and further work should be devoted to this problem. The effect of potassium fertilization upon the nitrogen content in all species of plants under all circumstances is not too clear because many other factors may have some influence on the intake of nitrogen (21).

During the growing period the lower leaves of the soybeans began to

TABLE 7. Chemical Composition of Grasses Grown in Pots on Bates Loam with Different Fertilizer Treatments.

Crop	Percent Potassium		Percent Phosphorus		Percent Calcium		Percent Nitrogen	
	1st cutting	2nd cutting	1st cutting	2nd cutting	1st cutting	2nd cutting	1st cutting	2nd cutting
Brome grass*	2.85	1.44	.12	.11	.69	1.20	2.91	2.67
Brome grass**	1.54	1.36	.13	.16	.95	1.10	2.55	2.96
Brome grass**	1.00	1.19	.14	.19	.96	1.07	2.52	2.95
Brome grass***	2.59	1.83	.11	.19	.77	.94	2.33	2.61
Brome grass***	2.41	2.56	.11	.17	.80	1.01	2.53	2.82
Rye grass*	4.41	2.11	.19	.10	xxx	1.02	3.77	2.38
Rye grass**	2.91	1.89	.23	.17	xxx	1.11	3.09	1.67
Rye grass**	2.61	1.19	.23	.15	xxx	1.09	3.48	2.17
Rye grass***	4.74	1.84	.20	.15	xxx	.92	3.50	2.30
Rye grass***	4.70	1.98	.22	.15	xxx	.98	3.62	2.35

* Soil received two tons of lime per acre.

** Soil received two tons of lime, 300 pounds of superphosphate, and 200 pounds of $(NH_4)_2 SO_4$ per acre.

*** Soil received two tons of lime, 300 pounds of superphosphate, 200 pounds of $(NH_4)_2 SO_4$, and 200 pounds of KCl per acre.

xxx Results inaccurate due to the improper adjustment of pH.

TABLE 8. Chemical Composition of Legumes Grown in Pots on Bates Loam with Different Fertilizer Treatments.

Crop	Percent Potassium	Percent Phosphorus	Percent Calcium	Percent Nitrogen
Big Hop*	2.08	.15	1.41	3.01
Big Hop**	1.58	.19	1.52	2.84
Big Hop**	1.44	.19	1.65	2.77
Big Hop***	2.20	.18	1.46	2.82
Big Hop***	2.09	.15	1.53	2.52
Crimson*	2.00	.15	1.97	2.62
Crimson**	1.56	.20	2.04	2.79
Crimson**	1.49	.19	1.97	2.73
Crimson***	2.24	.16	1.80	2.71
Crimson***	2.43	.17	1.86	2.63
Alfalfa*	1.85	.11	1.71	2.76
Alfalfa**	1.05	.15	1.57	2.72
Alfalfa**	1.13	.16	1.47	2.92
Alfalfa***	1.98	.17	1.56	2.85
Alfalfa***	1.80	.17	1.53	2.90
Soybeans*	1.22	.21	2.09	2.62
Soybeans**	1.05	.25	2.28	2.70
Soybeans**	.91	.24	2.53	2.86
Soybeans***	1.77	.22	2.17	2.94
Soybeans***	1.57	.22	2.09	2.61
Sweet Clover*	1.59	.12	2.21	3.05
Sweet Clover**	1.32	.14	1.76	2.77
Sweet Clover**	1.18	.15	1.73	2.75
Sweet Clover***	1.82	.14	1.42	2.70
Sweet Clover***	1.95	.13	1.61	2.90
Vetch*	1.70	.17	1.54	3.53
Vetch**	1.34	.19	1.21	2.90
Vetch**	1.30	.22	1.46	3.02
Vetch***	2.03	.17	1.24	2.86
Vetch***	2.26	.18	1.38	2.97
Lespedeza*	.94	.14	1.71	2.58
Lespedeza**	.97	.22	1.71	2.81
Lespedeza**	.94	.18	1.60	2.65
Lespedeza***	1.17	.19	1.67	2.74
Lespedeza***	1.27	.21	1.65	2.78

* Soil received two tons of lime per acre.

** Soil received two tons of lime, 300 pounds of superphosphate, and 100 pounds of $(NH_4)_2 SO_4$ per acre.

*** Soil received two tons of lime, 300 pounds of superphosphate, 100 pounds of $(NH_4)_2 SO_4$, and 200 pounds of KCl per acre.

die and fall from the plant. At this point it was decided to analyze the top leaves, bottom leaves, and stems of the soybean plants separately in an effort to determine if a variation in chemical content might exist. These data are presented in Table 9.

As stated previously potassium fertilization increased the potassium content of the entire soybean plant. Similar results were obtained when different parts of the plant were analyzed. The potassium content was higher in the top leaves, bottom leaves, and stems as a result of potassium fertilization. The bottom leaves showed a decrease in potassium content when compared with the top leaves. This indicates that potassium is mobile and migrates from the older leaves to the younger ones. The percentage of potassium in the stems was intermediate between the bottom and top leaves.

The phosphorus content of the top leaves was greater than either the bottom leaves, or stems, with the highest percentage occuring in the leaves of those plants that received potassium fertilization. Evidently phosphorus tends to move to the younger tissue also. The bottom leaves showed a marked decrease in phosphorus content when compared with the top leaves and a slightly lesser value when compared with the stems.

The calcium content of the top leaves was less than that of the bottom leaves but greater than the stems. The higher calcium concentration occuring in the bottom leaves indicate that calcium does not move about in the plant, but tends to accumulate as the tissues become older. In every case the calcium percentage was lower in the leaves and stems of those plants that had received potassium fertilization.

The top leaves contained more nitrogen than the bottom leaves as would be expected in the younger parts of the plant, but there was no indication that potassium fertilization increased the nitrogen content.

TABLE 9. Chemical Composition of Top Leaves, Bottom Leaves, and Stems of Soybeans Grown in Pots on Bates Loam with Different Fertilizer Treatments.

	Percent Potassium			Percent Phosphorus			Percent Calcium			Percent Nitrogen		
Treatment	Top Leaves	Bottom Leaves	Stems	Top Leaves	Bottom Leaves	Stems	Top Leaves	Bottom Leaves	Stems	Top Leaves	Bottom Leaves	Stems
L*	1.68	.95	1.02	.25	.17	.20	2.02	2.63	1.62	3.78	2.80	1.29
LNP	1.34	.97	.85	.31	.24	.21	2.13	3.25	1.47	3.94	---*	1.23
LNP	1.41	.52	.81	.32	.19	.21	2.16	4.04	1.40	4.12	---*	1.40
LNPK	2.05	1.52	1.73	.27	.19	.20	1.95	3.22	1.34	4.08	---*	1.73
LNPK	2.04	.99	1.67	.28	.17	.22	1.66	3.20	1.41	3.72	---*	1.36

* Lime
---* Not enough sample for analysis

The top leaves showing the greatest nitrogen content had been fertilized with lime, nitrogen, and phosphorus. The stems contained a smaller amount of nitrogen than either the bottom or top leaves.

SUMMARY

A study was made of the response of two grasses and eight legumes to potassium fertilization when planted on soils low and very low in exchangable potassium. These experiments were conducted in a greenhouse on a Bates loam, from Chelsea, Oklahoma, which had an exchangable potassium content of eighty-two pounds per acre and a Bowie very fine sandy loam, from Atoka, Oklahoma, which had an exchangable potassium content of thirty-eight pounds per acre.

Five pots of each soil were fertilized as follows. One pot of soil was treated with lime alone, duplicate pots were fertilized with lime, nitrogen, and phosphorus and with lime, nitrogen, phosphorus, and potassium. The moisture content of each soil was adjusted to seventy-five percent field capacity, at the time of planting, and this value was maintained by adding distilled water at regular intervals. After each watering the pots were rotated to insure as near identical light conditions as possible. The plants were harvested for analysis as soon as they appeared to be nearing maturity.

Response of the different crops to potassium fertilization was determined by calculating the percentage increase of air dry forage produced by the potassium fertilized plants and using those that were fertilized with lime, nitrogen, and phosphorus as a basis for comparison.

The crop showing the greatest response to potassium fertilization on the Bowie soil was big hop clover. The second cutting of rye grass and all of the clovers, except lespedeza and sweet clover, appeared to be affected by a lack of other soil nutrients, probably magnesium and some of the minor elements. Lespedeza and sweet clover did not respond to potassium fertilization on the Bowie soil but they made a good

growth indicating that both are well adapted to soils low in exchangable potassium. Rye grass appears to respond to potassium fertilization when grown on soils very low in exchangable potassium.

Chemical analyses of the plants grown on the Bowie soil established a definite potassium pattern that was similar for all plants. Potassium fertilization always increased the potassium percentage of the plants and had very little effect upon the phosphorus content of plants, raising it in some cases and lowering it in others. As the potassium content of a plant increased the calcium and magnesium content decreased. The Bowie soil showed a definite lack of magnesium as the calcium-magnesium ratio of the plants was very wide. A correlation of the effect of potassium fertilization upon the nitrogen content of the plants could not be determined.

The crop showing the greatest response to potassium fertilization on the Bates soil was big hop clover, with soybeans second. A decrease in the yield of brome grass occured on the second cutting. The response of rye grass to potassium fertilization increased on the second cutting. All of the legumes produced a satisfactory growth with the exception of Ladino clover. Alfalfa did not yield too well indicating that some other plant nutrient or nutrients were limiting factors in plant development. Lespedeza responded to potassium fertilization on the Bates soil.

Crimson clover responded to potassium fertilization with a 1000 pound forage increase per acre.

Vetch and sweet clover produced only a small response to potassium, but a large response to lime and phosphorus.

Chemical analyses of plants produced on the Bates soil had a similar potassium pattern as those on the Bowie soil.

Potassium fertilization decreased the calcium content of each of the crops except alfalfa and lespedeza and had very little effect upon the phosphorus content. Big hop clover, crimson clover, soybeans, and sweet clover showed a decrease in phosphorus content as the potassium content increased.

The top leaves, bottom leaves, and stems of soybeans, cut at the bloom stage, were analyzed separately, and it was found that potassium and phosphorus move from the older leaves to the younger ones. The nitrogen content was greater in the top leaves than any other part of the plant. Calcium did not move to the younger tissues, the bottom leaves containing a higher percentage than the top leaves.

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