THE EFFECT OF POTASSIUM FERTILIZER ON ALFALFA AND FORAGE SORGHUM

By

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THE EFFECT OF POTASSIUM FERTILIZER

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CHAPTER I

INTRODUCTION

Forage crop production is one of Oklahoma's most important enterprises. In this state there are an estimated 4.5 million acres devoted to introduced species which respond well to commercial fertilizers, especially nitrogen and phosphorus. At the present time there are about 500,000 acres of alfalfa and 400,000 acres of forage sorghum harvested annually in Oklahoma. The total acreage of introduced species has been steadily increasing, and the trend shows promise of continuing (16)[1]. As a result, there has been a tremendous increase in the amount of fertilizer applied to forage crops in order to achieve high yields.

As the use of fertilizers for forage production has increased, a number of problems have received increased attention. One of these problems concerns nitrate toxicity in livestock. Under some conditions high rates of nitrogen fertilizer can cause free nitrate to accumulate in plants in concentrations large enough to become toxic to animals that consume the plants (3, 6). This aspect of plant nutrition is especially important in forage crop production since these crops are used almost entirely for the production of livestock. Ruminant animals consume the majority of Oklahoma's forage crops. Likewise, ruminant animals are most susceptible to nitrate toxicity.

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[1] Figures in parenthesis refer to Literature Cited

Another aspect of forage crop production that is worthy of attention in Oklahoma is the proper use of potassium fertilizer. In north-central Oklahoma, farmers commonly apply potassium to the soil simply because they consider it cheap insurance. As the efficiency of production becomes more critical, it is important to know if potassium fertilization can increase forage yields on those soils.

This study was designed to determine whether potassium fertilization can increase forage production and decrease the amount of non-protein nitrogen by increasing the amount of true protein in alfalfa and forage sorghum.

CHAPTER II

LITERATURE REVIEW

One of the major functions attributed to potassium in plants is that of regulating nitrogen metabolism. The exact mechanism by which potassium functions in this process is unknown; however, a number of workers have reported the various effects of potassium deficiencies.

In 1934, Hartt (13) reported the effects of potassium shortage on protein synthesis and translocation in sugarcane. She found an accumulation of amino-nitrogen, indicating the potassium deficient plants were unable to synthesize proteins normally. Steward and Preston (21), working with potatoes, found that added potassium increased the rate of protein synthesis. Wall (23), in 1940, reported that potassium-deficient tomatoes tend to accumulate amides and free acids.

Some of the first evidence to indicate that potassium is directly involved in the synthesis of peptide linkages was started by Webster (25), who found that potassium ions enhance the rate of glutathione synthesis in plant extracts. He also showed that the rate of synthesis was depressed when potassium was removed by dialysis. Webster and Varner (27) and Snoke et al. (20) pursued this same idea and found that potassium stimulated the synthesis of glutathione, and other monovalent cations had little or no effect on the reactions. Later, Webster (26) tested five monovalent cations to determine their effect on the incorporation of glutamate into protein.

He found that potassium ions markedly increased the amount of glutamate incorporated into protein, but the other monovalent cations either depressed or had no effect on the reaction.

Griffith et al. (12) applied various nitrogen and potassium fertilizer rates to orchardgrass and found that high nitrogen rates increased the severity of the potassium deficiency where no potassium was applied. The potassium deficiency was accompanied by an abnormally high accumulation of asparagine in the forage. Asparagine accumulation was greatest with high nitrogen rates and low potassium levels. When the potassium content was less than 1.6% of the dry matter of the forage, asparagine accumulation was especially apparent.

Cummings and Teel (8) also performed nitrogen and potassium studies on orchardgrass. They found that high nitrogen rates increased the level of non-protein nitrogen in potassium deficient plants. Increasing the potassium content resulted in an increase of true protein and decrease in the amount of malate. Nitrogen alone increased malate content of the plants. They concluded that increasing the potassium content results in forage with more true protein, less non-protein nitrogen (NPN) and less malate even though potassium had no effect on total nitrogen content.

Barker and Bradfield (1) found that higher potassium concentrations, up to 250 PPM, decreased absolute and relative amounts of asparagine in corn grown in nutrient solutions. They found a decrease in total free amino acids with potassium increases to 250 PPM, but these relationships did not persist when potassium was increased to 500 PPM in the soltuion. Since large amounts of potassium decreased asparagine

and glutamine but increased aspartic and glutamic acids, they concluded that potassium causes amino acid incorporation into protein.

Teel (22) found that NPN and free alpha-amino nitrogen are directly related to nitrogen supply only if potassium is deficient. He states that when potassium is adequate, higher nitrogen rates do not increase NPN and free alpha-amino nitrogen found in orchardgrass.

Prianishnikov (17) has indicated that asparagine accumulation is due to a high expenditure of energy materials whereby protein is broken down. When the liberated amino acids are oxidized, ammonium concentrations are increased. He states that asparagine formation is a mechanism to prevent ammonium toxicity.

A number of workers have shown that potassium is required for pyruvic kinase to catalyze phosphoenol pyruvate (PEP) to pyruvate (9, 14, 15). One of the best accepted explanations for asparagine accumulation in potassium-deficient plants is that PEP forms oxalacetate instead of pyruvate. Oxalacetate is the precursor of aspartic acid which readily forms asparagine, especially if high nitrogen concentrations are present. This same mechanism could partially control the amount of pyruvate entering the Kreb cycle and thus reduce ATP synthesis which is necessary for protein formation (12).

Seay et al. (18), concluded that alfalfa should contain at least 1.25% potassium at hay stage in order to maintain high production and good stands. Chandler et al. (7) concluded that alfalfa could be expected to give yield responses to potassium fertilization if potassium content was less than 1.25% of the dry weight at early bloom stage. They recommend the potassium content of alfalfa be kept between

1.3% and 1.7% of the dry weight. When the exchangeable potassium content of the soil was greater than 80 pounds per acre, they got no yield responses to potassium fertilization. Based on a survey of soils and alfalfa from eleven states, Bear and Wallace (2) suggest 1.4% potassium in the forage and 80 pounds of exchangeable potassium per acre as being critical minimum values for sustained alfalfa production.

Blaser (4) states that alfalfa should be 2.0 to 2.5% potassium to obtain maximum yields from alfalfa-orchardgrass mixtures. Wallace and Bear (24) found alfalfa yields to increase with potassium content up to 3% potassium in plants grown in sand.

CHAPTER III

ALFALFA FERTILIZATION EXPERIMENT

This experiment was designed to achieve four primary objectives. They are as follows:

1. To determine the effect of various potassium levels at a high and low rate of soil phosphorus.
2. To determine if there is a response to nitrogen or sulfur fertilization on a Bethany silt loam in north-central Oklahoma.
3. To determine the potassium content of plant tissue at four levels of soil potassium and a high level of soil phosphorus.
4. To determine if potassium content in plants can alter nitrogen metabolism.

Materials and Methods

The experiment was located five miles north of Deer Creek, Oklahoma in Grant County (E½ SE¼ Sec. 21, T28N, R3W). The treatments were applied to a four year old stand of Buffalo alfalfa on Bethany silt loam soil. A drill-type applicator was used to place the fertilizer in the soil at a depth of about one and one-half inches. The treatment date was March 27, 1965, which was just prior to the start of spring growth.

Soil samples were collected from the study area before the treatments were applied. Samples were taken from both the surface soil and subsoil and analyzed separately. The soil was analyzed for available phosphorus

according to the methods of Bray and Kurtz (5). Exchangeable potassium was determined by using ammonium acetate extractant and a Beckman DU spectrophotometer. Soil pH was determined by use of a Beckman glass electrode pH meter.

The field design was a randomized block with four replications. Each plot was 6 feet by 30 feet. Yields were determined by weighing the alfalfa harvested in a 3 X 20 ft. swath taken from the center of each plot.

Alfalfa samples were collected for chemical analyses in the laboratory at three growth stages of each cutting. Samples were taken during early rapid growth, intermediate growth and at hay stage. At the same time the samples were collected for quantitative analyses, tissue tests were made in the field to determine potassium content of the cell sap in the alfalfa. These laboratory and field tests were made only on plants that received no nitrogen and the high rate of phosphorus. In the laboratory, total phosphorus was determined by the colormetric procedure as outlined by Shelton and Harper (19). The Beckman DU spectrophotometer was used to determine the amount of potassium, sodium, calcium and magnesium in the filtrate obtained in the phosphorus determination.

Results and Discussion

Precipitation during the 1965 growing season was below normal (Table I). As a result, only three hay cuttings were taken to obtain yield data. These cuttings were made on May 8, June 28 and September 9. On August 3, the alfalfa was clipped and removed from the plots, but weights were not taken because all the plants were stunted as a result of the previous drought. At that time the alfalfa was 4 to 6 inches tall and in the full

TABLE I.

PRECIPITATION AT BLACKWELL, OKLAHOMA DURING 1965*.

Month	Inches Received	Departure from normal in inches
January	.56	- .48
February	.74	- .48
March	1.10	- .50
April	1.21	-1.59
May	2.93	-1.00
June	2.16	-1.62
July	6.27	3.20
August	3.69	.69
September	3.58	.68
October	.54	-1.74
Total	22.78	-2.84

*Weather station is 15 miles east and 5 miles south of alfalfa plots.

bloom stage. It was clipped to assure more uniform regrowth as moisture became available. Also, it would have been undesirable for the stunted plants to be included in the chemical analysis of samples collected from the September cutting.

A statistical analysis of the three individual alfalfa cuttings indicated there was no significant yield response to any of the treatments in the experiment. That is, there was no significant yield increase due to nitrogen, phosphorus, potassium or sulfur in any of the combinations applied (Table II).

Because every plot received at least 80 pounds of P_2O_5 per acre, there are no data to determine if there was a significant response to phosphorus at the 80 pound rate. However, the soil test data in Table III indicate that a yield response could be expected from additions of phosphorus fertilizer. Furthermore, the extremely low phosphorus content of the alfalfa from the May cutting indicated that phosphorus was deficient at that time (Table IV). As the season progressed and the applied phosphorus was taken up by the alfalfa, the phosphorus content of the forage was greatly increased. This result is of particular importance to livestock producers since phosphorus is often a limiting nutrient in livestock receiving all roughage diets.

Further evidence to indicate a response to phosphorus at the 80 pound rate was the fact that the alfalfa in the plots was larger, more vigorous, and had a darker green color than the alfalfa outside the plots. This observation became progressively more apparent throughout the summer and was most obvious at the time of the September cutting.

TABLE II.

TOTAL ALFALFA YIELD FOR THE 1965 GROWING SEASON

Treatment	Pounds Per Acre*
0-80-0	5555
0-80-40	5275
0-80-80	5028
0-80-160	5166
0-240-0	5622
0-240-40	5220
0-240-80	5147
0-240-160	5374
40-80-80**	5251
40-240-80**	5724
40-80-80 #	4990
40-240-80 #	5485

* Data represent the average of four replications.

** NH_4NO_3 was the source of nitrogen.

\# $(NH_4)_2SO_4$ was the source of nitrogen.

TABLE III.

SOIL TEST DATA FOR BETHANY SILT LOAM

Depth	Available P lbs./A.	Exchangeable K lbs./A.	pH
Surface	19	625	5.9
Subsoil	11	654	5.9

TABLE IV.

CHEMICAL ANALYSIS OF ALFALFA*

Harvested May 8, 1965				
Treatment	% K	% Ca	% Mg	% P
0-240-0	2.30	1.44	.83	.06
0-240-40	2.32	1.44	.82	.06
0-240-80	2.19	1.49	.85	.05
0-240-160	2.36	1.53	.79	.05
Harvested September 9, 1965				
Treatment	% K	% Ca	% Mg	% P
0-240-0	2.22	1.32	.80	.22
0-240-40	2.27	1.32	.83	.27
0-240-80	2.31	1.23	.80	.28
0-240-160	2.43	1.22	.82	.28

* Reported values represent the average of four replications. Sodium was present in trace amounts only.

The total yield of the three cuttings is given in Table II. The average yield per acre was about 5,300 pounds which was slightly below the three ton yield that can normally be expected from alfalfa on Bethany silt loam in Grant County. This lower yield was probably a result of the low moisture during the growing season (Table I).

The tissue tests that were made in the field were designed to indicate low, medium or high potassium content. Low, medium and high correspond to 1,000, 2,000 and 3,000 PPM potassium, respectively. In all cases the tissue tests showed a low potassium content in the forage, indicating less than 1,000 PPM potassium in the cell sap. However, quantitative potassium determinations of samples in the laboratory consistently showed greater than 2.0% total potassium or 20,000 PPM total potassium in the alfalfa. Since 2.0% total potassium is more than adequate for normal growth of alfalfa, the tissue tests did not give a valid indication of plant requirements.

There was no significant change in potassium content of the forage due to potash treatments (Table IV). In fact, the potassium content did not change significantly from the May cutting to the September cutting. The soil test data indicate that this result should have been expected.

Because there was no change in potassium content of the forage due to potassium treatments of the soil, no conclusions can be drawn concerning the effect of soil potassium on the potassium content in the plants. For the same reason, nitrogen in the plants was not fractionated into protein and non-protein nitrogen to determine whether potassium alters nitrogen metabolism.

Summary and Conclusions

An established stand of Buffalo alfalfa was fertilized with nitrogen, phosphorus, potassium and sulfur. There was no significant yield response to any treatment in the experiment. The phosphorus content of the alfalfa was greatly increased during the season by phosphorus treatments. Tissue tests were highly inadequate for determining plant needs for potassium. Potassium content of the alfalfa was not changed by potash treatments.

CHAPTER IV

FORAGE SORGHUM ANALYSIS

The data obtained in this laboratory experiment came from a forage sorghum fertility test near Muskogee, Oklahoma. The primary objective was to determine if the potassium content in forage sorghum changed the nitrogen metabolism.

Materials and Methods

Sugar drip forage sorghum was grown on a Parsons silt loam soil at the Eastern Oklahoma Pasture Improvement Station near Muskogee, Oklahoma. The experimental design was a randomized block with four replications. The fertility treatments included four nitrogen rates, three potassium rates and two phosphorus rates (Table V).

When the sorghum was in the early boot stage, samples were collected for chemical analyses in the laboratory. A period of approximately six hours elapsed from the time the samples were collected until they could be placed in the oven to dry. Samples were divided into young leaves, old leaves and stalks, and each group was analyzed separately. Young leaves and old leaves refer to the three youngest and three oldest leaves on the plant, respectively. Stalks included the entire stalk with the sheath removed. Three stalks were taken at random from the second and fifth rows of each plot, making a total of

six stalks per sample. The oven-dry weight of the stalks was recorded as a possible means of evaluating growth differences at the time the samples were taken (Table V).

Total phosphorus was determined by the methods of Shelton and Harper (19). The Beckman DU spectrophotometer was used to determine total potassium, sodium, calcium and magnesium in the filtrate obtained in the phosphorus determination.

Nitrogen in the forage was separated into protein and non-protein nitrogen (NPN) by extracting the NPN with 80% ethanol for 48 hours. The Kjeldahl procedure was used to determine the amount of NPN extracted and to determine total nitrogen in the samples. Protein nitrogen was taken as the difference between total nitrogen and NPN.

TABLE V

YIELD OF FORAGE SORGHUM

Treatment	Dry Stalk Wt. g/6 stalks	Dry Matter lbs./A
0-60-40	213	11,580
40-60-40	189	10,960
80-60-40	145	12,080
120-60-40	154	10,430
80-0-40	115	8,565
80-60-0	138	10,310
80-60-80	162	11,225

Results and Discussion

There was no significant yield response to any treatment in the experiment. Visual differences seemed apparent at the time the samples were collected, but stalk weights at that time failed to show any significant responses (Table V). Moisture was probably the primary factor limiting responses since 1965 was an exceptionally dry growing season at Muskogee (Table VI). The soil test data in Table VII indicate there should have been a response to phosphorus. Furthermore, nitrogen and phosphorus responses have been obtained from forage sorghum growing on this same soil in previous years.

The data obtained from the chemical analysis of the young leaves are summarized in Table VIII. There was no significant change in potassium, total nitrogen or protein content of the leaves due to nitrogen treatments. Since nitrogen is a mobile element in plants, any nitrogen deficiency should show up last in the young meristematic areas, as is the case here. Nitrogen stresses could be expected to occur in older plant parts.

There was a significant increase in NPN in the young leaves as the nitrogen rates were increased. Here, the excess nitrogen moving into the young leaves was not being incorporated into protein. Beeson (3) points out that greater than 0.3% nitrate in feed presents a potential hazard to livestock. In these young leaves there was a maximum of only 0.5% NPN which was by no means all nitrate since all forms of free nitrogen were included.

TABLE VI.

PRECIPITATION AT MUSKOGEE, OKLAHOMA

DURING 1965 GROWING SEASON.

Month	Inches Received	Departure from Normal in inches
January	2.70	.40
February	1.97	- .66
March	1.78	-1.45
April	6.76	2.22
May	4.15	-1.60
June	5.31	- .17
July	2.83	- .32
August	5.16	2.27
September	2.57	- .92
October	.07	-3.35
Total	33.30	-3.58

TABLE VII.

SOIL TEST DATA

Soil Type	% OM.	Avail. P_2O_5	Exch. K	pH
Parsons silt loam	2.30	3 lbs./A	89 lbs./A.	5.3

TABLE VIII.

ANALYSIS OF FORAGE SORGHUM YOUNG LEAVES.

Treatment	% K *	% Total N	% NPN *	% Protein
0-60-40	1.16 a	1.87 a	.34 a	9.56 a
40-60-40	1.09 a	2.07 a	.42 b	10.27 a
80-60-40	1.06 a	2.10 a	.49 c	10.05 a
120-60-40	1.14 a	2.15 a	.51 c	10.25 a
80-60-0	.55 a	2.15 a	.49 a	10.38 a
80-60-40	1.06 b	2.10 a	.49 a	10.05 a
80-60-80	1.30 c	2.12 a	.49 a	10.17 a
80-0-40	1.34 a	2.23 a	.46 a	11.10 a
80-60-40	1.06 b	2.10 a	.49 a	10.05 a

* Numbers within a group followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

The potassium treatments consistently increased the amount of potassium in the sorghum, but caused no significant change in total nitrogen, NPN, or protein content. Other workers have reported that yield responses can be expected from alfalfa if the potassium content is less than 1.25% (7, 18). Here, the forage sorghum contained as low as 0.55% potassium, yet no yield response was obtained. Again the low moisture may have been a contributing factor; however, the critical value probably changes with species.

The phosphorus rates had no effect on nitrogen metabolism. However, where no phosphorus was applied, the potassium content of the forage was consistently higher. Similar results were found by Gervais et al. (10, 11).

Table IX contains the results from the chemical analysis of the stalks. The effects of nitrogen stresses were more apparent in this analysis than in the case of the young leaves. At the low nitrogen rates the nitrogen content of the stalks dropped markedly as the mobile nitrogen moved to the more active meristematic areas. The higher nitrogen rates decreased the nitrogen stress and, therefore, more nitrogen was left in the stalks. As a result the total nitrogen, NPN and protein content of the stalks consistently increased as nitrogen rates increased.

Again, the potassium rates were consistently reflected by the increased potassium content of the stalks, but did not significantly alter nitrogen metabolism. The potassium content was highest in plants receiving no phosphorus treatment.

TABLE IX.

ANALYSIS OF FORAGE SORGHUM STALKS

Treatment	% K *	% Total N *	% NPN *	% Protein*
0-60-40	.42 a	.34 a	.11 a	1.44 a
40-60-40	.39 a	.61 ab	.26 ab	2.21 a
80-60-40	.40 a	.95 bc	.39 bc	3.71 b
120-60-40	.48 a	1.15 c	.46 c	4.30 b
80-60-0	.26 a	1.07 a	.44 a	3.93 a
80-60-40	.40 b	.95 a	.39 a	3.71 a
80-60-80	.67 c	.86 a	.34 a	3.31 a
80-0-40	.61 a	1.09 a	.45 a	4.03 a
80-60-40	.40 b	.95 a	.39 a	3.71 a

* Numbers within a group followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

The forage sorghum samples were analyzed for phosphorus, potassium, sodium, calcium and magnesium (Table X). However, the old leaves were so severly dried and deteriorated that there was not enough plant material to make the nitrogen studies. There is little doubt that their nitrogen content was extremely low. Because of the deteriorated condition, the results from the analysis of these leaves would have been of questionable value in this study had the analysis been made.

TABLE X.

FORAGE SORGHUM ANALYSIS*

	Young Leaves			Old Leaves			Stalks		
Treatment	% K	% Ca	% Mg	% K	% Ca	% Mg	% K	% Ca	% Mg
0-60-40	1.16	.21	.20	.32	,69	.43	.42	.24	.02
40-60-40	1.09	.26	.29	.41	.66	.58	.39	.24	.08
80-60-40	1.06	.27	.37	.38	.65	.52	.40	.30	.20
120-60-40	1.14	.25	.35	.68	.63	.56	.48	.26	.23
80-0-40	1.34	.16	.14	.76	.44	.19	.61	.33	.12
80-60-0	.55	.32	.38	.16	.98	1.04	.26	.30	.15
80-60-80	1.30	.26	.25	.89	.54	.34	.67	.25	.14

* Data represent the average of four replications.

Sodium was present in trace amounts only.

Summary and Conclusions

Plant samples were collected from sugar drip forage sorghum when it was in the early boot stage. The sorghum had been fertilized with four rates of nitrogen, three rates of potassium and two rates of phosphorus. The samples were analyzed for total nitrogen, non-protein nitrogen and protein content. Total phosphorus, potassium, sodium, calcium and magnesium was also determined.

Although potassium content of the forage was significantly increased by increasing potassium treatments, there was no change in nitrogen metabolism due to different potassium levels. Increasing nitrogen rates consistently increased all forms of nitrogen in the plants.

There was no significant yield response due to any treatment in the experiment. Moisture was considered the most limiting factor.

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Master of Science

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