YIELD RESPONSE OF ALFALFA TO FERTILIZATION WITH PHOSPHORUS, POTASSIUM AND BORON IN COMPLETE FACTORIAL FIELD AND GREENHOUSE EXPERIMENTS

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I INTRODUCTION

Alfalfa has long been recognized as an outstanding hay plant in terms of both forage yield and feeding value. More recently, this crop has become recognized as a high value pasture species when combined in grass-legume mixtures.

The planting of alfalfa in Oklahoma dates back to the beginning of agriculture in the state and has become the most important legume hay crop in the state (7).[/1] In 1958 alfalfa occupied 383,000 acres of land yielding more than 900,000 tons of forage (32).

Alfalfa has a rather wide range of adaptation to soil types; but deep, permeable, well drained, medium textured soils are most desirable. Alfalfa can be grown on much of the cultivated land in central and eastern Oklahoma with proper soil treatment and management.

The Oklahoma Agricultural Experiment Station has initiated a comprehensive research study concerning the soil fertility requirements for alfalfa grown on various soil types within the state. The objective of this study was to determine the effects of various soil fertility treatments on yields of alfalfa. Studies include both field and greenhouse experiments concerned with different levels and combinations of phosphorus, potassium and boron.

/1 Figures in parenthesis refer to Literature Cited.

II REVIEW OF LITERATURE

Alfalfa has a high plant nutrient requirement. Yield, quality and stand are materially depressed on deficient soils. Adequate available phosphorus, potassium and boron are of particular importance for alfalfa production. Alfalfa has shown response to some type of fertilizer treatment on most soils east of the 95th meridian (17).

Nielson reporting on work done in Utah (31), found there was no critical time for application of phosphate fertilizer. However, Seay and Weeks (38) indicated that the best time for application was during the fall. They also found that phosphorus was taken up by alfalfa during the dormant season of the year. Woodhouse (40) found that alfalfa has a high requirement for phosphorus.

Investigators have shown that the residual effects of rock phosphate may last for several years, while superphosphates do not have such a residual effect (11, 26). Larson (23) found that yields of oats and alfalfa were markedly increased by phosphate application to the soil. The first two crops followed a curve of diminishing returns. Later, however, the increment of 30 pounds of P_2O_5 per acre became ineffective. During the first two years of the experiment, a corresponding increase in phosphorus content in the plant was related to the phosphate applied. The uptake of calcium decreased correspondingly at the same rates.

MacLean and Cook (24) studied the effects of soil reaction on phosphorus availability. They found that liming slightly above the neutral point increased the amount of available phosphorus. Studies on Washington soils by Hausenbuiller and Weaver (16) showed that phosphate fertilizers were neither leached from the soil nor converted into an unavailable form. Hunter (17) stated that the level of available phosphorus in the soil was the most important factor affecting the phosphorus content of alfalfa.

Millar (28) reported that over 80 percent of the phosphorus applied to American soils in fertilizers is in forms designated as available. Five to fifteen percent of this available phosphorus is recovered in the first crop harvested after application. The loss of available phosphorus is due to reversion from a soluble form to an unavailable form. Murphy (29) has shown that phosphate fixation may occur in soils high in kaolin clay minerals. He stated that this probably accounts for the phosphate that is fixed at neutrality. However, the fixation power of most clay minerals is relatively low.

Unless strict attention is given to the mineral nutrition of alfalfa, the maintenance of a good stand for more than a few years is often difficult. Gerwig and Ahlgren (12) found potassium was the most important factor in maintaining high yields and persistence of an alfalfa stand. In 1953, their results indicated that plants receiving potash showed significantly higher yields at the 1% level. Woodhouse (40) found that application of potassium aided in stand maintenance of alfalfa and decreased the number of weeds as compared to alfalfa stands which received no potash.

Seay (37) obtained a linear relationship between the potassium content of alfalfa and the logarithm of the number of pounds of exchangeable potassium per acre in the soil on which the crop was grown.

Brown (5) in studies of potassium and boron fertilization of alfalfa on some Connecticut soils, found that large applications of K_2O, before planting, produced alfalfa of high potassium content and low calcium content the first year, but the reverse the third year. This treatment also resulted in poorer stands than where potassium treatments were divided into annual applications.

Jenny and Shade (20) showed that lime additions to clay minerals liberated adsorbed potassium in large amounts. Bear (2) found that when large amounts of potassium were available to plants, the uptake of calcium and magnesium was greatly reduced.

Chandler (8) stated that potassium content of alfalfa was a reliable criterion for predicting the need of potassium fertilization of alfalfa. When alfalfa contained less than 1.25 percent potassium at the early bloom stage, a profitable yield response usually resulted from potassium fertilizer applications. When potassium content was over 1.25 percent, there was seldom any response to potassium fertilization.

Peech and Bradfield (33) stated that potassium uptake was not affected appreciably by calcium, whereas potassium suppressed the uptake of both calcium and magnesium. Murphy (30) found that soils containing less than 60 ppm. of replaceable potassium generally responded to potassium fertilization if other factors were favorable for plant growth.

Boron was one of the first trace elements to be recognized as an essential element for the nutrition of plants. Alfalfa has been shown to be especially sensitive to a shortage of available boron in the soil.

Johnson and Scarseth (21) found plant growth under boron deficient conditions showed extremely poor growth of roots, brittleness of the stem and petiole, breakdown of conducting tissue and even death of the terminal buds. Haas and Klatz (14) stated that boron was essential to cell division. They found that the cambium and a portion of the phloem were disintegrated. In alfalfa, Scripture and McHargue (36) found that soluble nitrogenous compounds and reducing sugars were present in greater quantities in the sap of boron deficient plants than in normal plants.

While boron is essential for normal growth of plants, concentrations of the element not greatly in excess of the optimum growth requirement are toxic to many species (1). The concentration range between the minimum amounts for plant growth and those which are toxic is relatively narrow. Stinson (39) found that the total boron content of alfalfa varied directly with the water soluble boron in the soil.

Brown and King (4) decreased boron deficiency symptoms, increased height by 15 percent and yield by 16 percent with application of boron. Boron content of the leaves was increased by 21 to 62 percent with the application of 20 pounds of borax per acre when compared with alfalfa which was not fertilized with boron. Crowder and Baird (10) found tremendous responses to boron. Alfalfa hay yields with 15 pounds of borax per acre averaged 2,490 pounds per acre and without borax 1,340 pounds per acre. Klemme (22) found in field studies with the light colored soils in Missouri that boron deficiencies can be prevented and acre yield of alfalfa hay be increased with boron fertilization.

The life of the alfalfa stand can be prolonged by applications of borax as stated by Hutchason and Cocke (18). They found that in the eastern section of Virginia, they could grow alfalfa and produce high yields by using good seed, lime, and heavy applications of phosphorus and potassium. These stands only persisted for short periods, usually being reduced to such an extent that they became uneconomical by the end of the second year. Boron was added, which corrected the yellowing and produced profitable stands for longer periods of time. Grizzard and Mathews (13) found that borax treated areas gave vigorous growth and good stands were maintained, while the untreated areas become thin within three years.

Stinson (39) concluded that the boron content of alfalfa increased and development of boron deficiency symptoms was prevented by the application of borax to the soil. There was visual evidence of increased growth, greater resistance to winter-killing, and a tendency to have a heavier seed set. He also found that there was a positive relationship between alfalfa maturity, soil productivity level and water soluble boron supply of the soil. Midgley and Dunklee (27) found that the second crop of alfalfa, which had been fertilized with borax, produced more than 35 times as much seed as the plants which received no boron.

Recommendations as to rate of application of borax vary from 15 to 100 pounds per acre. Colwell and Boker (9) found that 40 pounds of borax gave good results on Idaho soils. Burris (6) obtained a yield increase from 40 pounds of borax applied per acre on a Norge fine sandy loam soil.

III MATERIALS AND METHODS

Soil Used in the Field and Greenhouse Experiment

The soil used in the field and greenhouse experiment was a Norge fine sandy loam. This soil was formed from old alluvium. The topsoil is about eight inches deep, dark brown in color, fine sandy loam in texture, and weak to medium granular in structure. It is friable and permeable. A detailed description is given in Manual of Soil Series of Oklahoma (25).

Results of the physical and chemical properties of the soil are reported in Table I. Available phosphorus was determined by leaching with 0.1 N acetic acid as proposed by Harper (15). Cation exchange capacity and exchangeable potassium were determined by the procedure presented by Jackson (19). Total nitrogen was determined by modification of the Kjeldahl method (34). The percentage organic matter was determined by the procedure outlined by Schollenberger (35). Soil reaction was determined using the Beckman glass electrode pH meter. Mechanical analyses were made by the hydrometer method essentially as presented by Bouyoucos (3).

TABLE I

SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NORGE FINE SANDY LOAM SOIL USED IN THE FIELD AND GREENHOUSE EXPERIMENTS (6)

Texture	
Percent sand	72.0
Percent silt	20.0
Percent clay	8.0
Reaction (pH)	6.5
Percent organic matter	1.00
Percent nitrogen	.02
Available phosphorus (pounds per acre)	10.90
Exchangeable potassium (meq. per 100 grams)	0.19
Cation exchange capacity (meq. per 100 grams)	4.18

Field Experiments

The field experiments reported in this study were conducted on a Norge fine sandy loam.

The plots were located on the Paradise farm about 9 miles south and 6 miles west of Stillwater, Payne County, Oklahoma in the SE¼ SE¼ Sec. 34, T18N, R1E.

The low phosphate experiment was established in 1956 and included annual applications of the following treatments:

P_1 = 40 pounds P_2O_5 per acre as treblesuperphosphate (45%)

P_2 = 80 pounds P_2O_5 per acre as treblesuperphosphate (45%)

K_1 = 100 pounds K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds borax per acre (11.39%)

The plots were laid out as a complete factorial in split plot randomized block design. Three hay cuttings were obtained in 1958 and the total yields are reported in Table II.

The high phosphate experiment was established in 1957 on the same soil as the low phosphate experiment with the following treatments:

P_3 = 120 pounds of P_2O_5 per acre as treblesuperphosphate (45%)

P_4 = 160 pounds of P_2O_5 per acre as treblesuperphosphate (45%)

P_5 = 200 pounds of P_2O_5 per acre as treblesuperphosphate (45%)

K_1 = 100 pounds of K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds of K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds of borax per acre (11.3%)

The plots were designed into a complete factorial in the same manner as the low phosphate experiment. Three hay cuttings were obtained in 1958 and the total yields are presented in Table III.

Hay samples were taken from all plots and weighed. The samples were then oven dried at 65° C. and reweighed. The yields were adjusted to a 14% moisture level.

Greenhouse Experiment

The objective of the greenhouse experiment was to determine the effects of three phosphate, three potassium and two boron levels on yield of alfalfa and to compare the results with those obtained from the field.

The soil was collected from the field in which the field experiments were located. The air dry soil was screened through a $\frac{1}{4}$ inch mesh screen. The soil was put into two gallon, glazed, earthenware pots at the rate of 20 pounds to a pot. Each of the 18 treatments were replicated four times giving a total of 72 pots. Calcium was added to adjust all treatments for the calcium added in 160 pounds of $Ca(H_2PO_4)_2 \cdot H_2O$ per acre.

The treatments were as follows:

P_1 = 80 pounds of P_2O_5 per acre as $Ca(H_2PO_4)_2 \cdot H_2O$

P_2 = 160 pounds of P_2O_5 per acre as $Ca(H_2PO_4)_2 \cdot H_2O$

K_1 = 200 pounds of K_2O per acre as KCl (60%)

K_2 = 400 pounds of K_2O per acre as KCl (60%)

B_1 = 80 pounds of $Na_2B_4O_7 \cdot 10H_2O$ (11.3%)

The treatments were mixed with the upper portion of the soil. The approximate moisture equivalent value was determined. The soil was then watered to approximate field capacity before planting.

On August 23, 1958, certified Buffalo alfalfa, Medicago sativa, was seeded in a circular fashion about ½ inch deep. The stand was adjusted to ten plants per pot. There were five cuttings taken beginning January 12, 1959 and ending May 12, 1959. The forage produced was oven-dried and weighed. The total yields are recorded in Table VI.

IV RESULTS AND DISCUSSION

Field Experiments

There were two field experiments established to study the effects of various soil fertility treatments on alfalfa yields. These were designated as: (1) low phosphate series and (2) high phosphate series. The treatment symbols explained below will be used in the discussion of the results.

Treatment Symbol	Fertilizer Material	Fertilizer Analysis 1/	Rate lbs/A
	LOW PHOSPHATE SERIES		
Check	No Fertilizer		
P_1	Treblesuperphosphate	(0-45-0)	88.8
P_2	Treblesuperphosphate	(0-45-0)	177.6
K_1	Muriate of potash	(0-0-60)	166.6
K_2	Muriate of potash	(0-0-60)	333.2
B_1	Borax	(11.3%)	40.0
	HIGH PHOSPHATE SERIES		
P_3	Treblesuperphosphate	(0-45-0)	266.4
P_4	Treblesuperphosphate	(0-45-0)	355.2
P_5	Treblesuperphosphate	(0-45-0)	444.0
K_1	Muriate of potash	(0-0-60)	166.6
K_2	Muriate of potash	(0-0-60)	333.2
B_1	Borax	(11.3%)	40.0

1/ Figures in parenthesis represent percent N - P_2O_5 - K_2O and B, respectively.

Forage yields for the low phosphate experiment in 1958 are reported in Table II. There were statistically significant yield differences as indicated by the F values from the analysis of variance. The treatment symbols used in this experiment are explained on page 11. Each figure is the average of three replications from a total of three cuttings during the season.

The average yield on the low phosphate series for all treatments was 6305 pounds of hay per acre. The highest total yield was obtained from the P_2K_1 treatment with 7121 pounds of hay per acre. The lowest yield was obtained from the B treatment with a total yield of 5475 pounds of hay per acre. The check (no treatment) was the next to lowest with 5522 pounds per acre.

The increase in yield due to phosphate fertilization was statistically significant at the one percent level. There was an increase in average yield with each increment of phosphate added. All plots which received phosphorus yielded more hay than the check plot.

Differences between the potassium treated plots and plots which received no potassium were statistically significant at the five percent level. The K_1 treatment gave an increase in yield in all cases; however, the K_2 treatments showed no increase over the K_1 treatments.

The yield difference as a result of the borax treatment was not statistically significant. There was a slight increase in total yield on the boron treated plots. Where boron was added to plots without phosphorus fertilization, there was a decrease in yield. However, where boron was added to plots with phosphorus fertilization, in general, there was a yield increase.

TABLE II

EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVEL, ON TOTAL YIELD OF ALFALFA HAY (14% MOISTURE), FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, 1958

Treatment Symbols 2/	Average Pounds Per Acre 1/						
	B_0			B_1			
	K_0	K_1	K_2	K_0	K_1	K_2	$\bar{X}$
P_0	5521.5	6163.9	6197.9	5474.7	5980.9	5976.7	5885.9
P_1	5883.1	6342.5	6163.9	6351.0	6648.8	6746.6	6355.9
P_2	6321.2	7121.0	6619.0	6546.7	6733.9	6704.1	6674.3
$\bar{X}$	5908.6	6542.4	6326.9	6124.1	6454.5	6475.8	6305.4
$B_0B_1\bar{X}$		6259.3			6351.5		

1/ Yield figures are the mean of three replications. F Values: P level 8.81**, K level 3.64*, B level <1 n.s., Error mean square 177.79.

2/ Treatment symbols are:
$P_0B_0K_0$ = No treatment

P_1 = 40 pounds P_2O_5 per acre as treblesuperphosphate (45%)

P_2 = 80 pounds P_2O_5 per acre as treblesuperphosphate (45%)

K_1 = 100 pounds K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds of borax per acre (11.3% boron)

* Significant at 5% level.
** Significant at 1% level.

There was no interaction between any of the three element treatments when analyzed statistically.

Forage yields for the high phosphate series in 1958 are presented in Table III. There were no statistically significant yield differences as indicated by the F values from the analysis of variance. The treatment symbols used in this experiment are explained on page 11. Each figure is the average yield of three replications and three cuttings.

The difference in yield per acre between the lowest and the highest yielding treatments was 1068 pounds. The lowest average yield of 5462 pounds of forage per acre was from plots which received only P_4. The highest average yield was obtained from the plots which received the P_3K_2 treatment. The overall average yield of all plots in the experiment was 5890 pounds of forage per acre.

Additions of phosphate above the P_3 level decreased yields slightly with the average yields being 5946, 5829, 5895 for P_3, P_4, P_5, respectively.

At the P_3 level there was an increase in yield with every increment of K added. However, there were no trends in the P_4 and P_5 levels. There was a slight increase in total yield where boron was added.

Hay yield from the low phosphate series for 1956, 1957 and 1958 field experiments are presented in Table IV. The phosphorus and potassium treatments produced statistically significant yield differences at the five percent level as indicated by the F values from the analysis of variance. The treatment symbols used are explained on page 11. Each figure is the average yield of three replications for the total production per year.

The difference in average yield per acre between the lowest and the

TABLE III

EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVEL ON TOTAL YIELD OF ALFALFA HAY (14% MOISTURE), FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, 1958

Treatment Symbols 2/	Average Pounds Per Acre 1/						
	B_0			B_1			
	K_0	K_1	K_2	K_0	K_1	K_2	$\bar{X}$
P_3	5615.1	5972.4	6529.7	5551.3	5874.6	6129.8	5945.5
P_4	5462.2	5921.4	5683.2	5989.5	5929.9	5985.2	5828.5
P_5	5776.7	5640.6	6053.3	6074.5	5946.9	5878.8	5895.1
$\bar{X}$	5618.0	5844.8	6088.7	5871.7	5917.1	5997.9	5889.7
$B_0B_1\bar{X}$		5850.5			5928.9		

1/ Yield figures are the mean of three replications. F values: P level <1 n.s., K level 2.1 n.s., B level <1 n.s., Error mean square 105.7.

2/ Treatment symbols are:

K_0B_0 = No treatment

P_3 = 120 pounds of P_2O_5 per acre as treble superphosphate (45%)

P_4 = 160 pounds of P_2O_5 per acre as treble superphosphate (45%)

P_5 = 200 pounds of P_2O_5 per acre as treble superphosphate (45%)

K_1 = 100 pounds of K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds of K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds of borax per acre (11.3% boron)

TABLE IV

EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVEL ON AVERAGE TOTAL YIELDS OF ALFALFA HAY (14% MOISTURE), FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, 1956, 1957, 1958

Treatment Symbols 2/	Average Total Pounds Per Acre Per Year 1/ B_0 K_0	B_0 K_1	B_0 K_2	B_1 K_0	B_1 K_1	B_1 K_2	$\bar{X}$
P_0	4194.3	4811.1	4802.6	4547.4	4883.4	4794.9	4672.1
P_1	4709.0	4874.9	4887.6	4921.7	5125.9	5036.6	4925.9
P_2	4781.3	5185.5	4768.6	4879.2	5270.6	5185.5	5011.8
$\bar{X}$	4561.5	4957.1	4819.6	4782.7	5093.3	5005.4	4869.9
$B_0 B_1 \bar{X}$		4779.4			4960.5		

1/ Yield figures are the mean of three replications and three years. F values: P level 3.71*, K level 3.86*, B level 3.09 n.s., Error mean square 747.0.

2/ Treatment symbols are:

$P_0K_0B_0$ = No treatment

P_1 = 40 pounds of P_2O_5 per acre as treble superphosphate (45%)

P_2 = 80 pounds of P_2O_5 per acre as treble superphosphate (45%)

K_1 = 100 pounds of K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds of K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds of borax per acre (11.3% boron)

* Significant at 5% level.

highest yielding treatment was 1076 pounds. The lowest average yield of 4194 pounds of hay per acre was from the plots which received no fertilizer (check). The highest average yield of 5271 pounds was from the plots which received the $P_2K_1B_1$ treatment. The overall average yield of all plots in the experiment was 4870 pounds of hay per acre.

The increase in yield due to phosphorus fertilization was statistically significant at the five percent level. There was an increase in average yield with each increment of phosphate added; the first increment giving the greatest increase and the second increment an additional increase.

The application of potassium gave a statistically significant yield increase as indicated by the F value from the analysis of variance. The average yield obtained from the K_2 was less than that of the K_1 treatment indicating that the first increment of potassium was enough to maintain high yields.

The application of boron gave no statistically significant yield differences as indicated by the F values from the analysis of variance. However, where phosphate was added there was an increase in average yield with the boron treatments. There was an average increase in yield of 191 pounds on the boron treated plots.

Forage yields for the 1957-58 high phosphate series are reported in Table V. There were no statistically significant yield differences between the fertility treatments as indicated by the F values in the analysis of variance. The treatment symbols used in this discussion are explained on page 11. Each figure is the average yield of three replications for the total production per year.

TABLE V

EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVEL ON AVERAGE TOTAL YIELDS OF ALFALFA HAY (14% MOISTURE), FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, 1957, 1958

Treatment Symbols 2/	Average Total Pounds Per Acre Per Year 1/ B_0 K_0	K_1	K_2	B_1 K_0	K_1	K_2	$\bar{X}$
P_3	3943.3	4181.6	4309.2	3751.9	3964.6	4347.5	4083.0
P_4	3824.2	4011.4	3943.3	4100.7	4134.8	3977.4	3998.6
P_5	4168.8	3939.1	4181.6	4168.8	4109.2	4066.7	4105.7
$\bar{X}$	3978.8	4044.0	4144.7	4007.1	4069.5	4130.5	4062.4
$B_0B_1\bar{X}$		4055.8			4069.3		

1/ Yield figures are the mean of three replications and two years. F values: P level <1 n.s., K level 1.5 n.s., B level <1 n.s., Error mean square 313.7.

2/ Treatment symbols are:

K_0B_0 = No treatment

P_3 = 120 pounds of P_2O_5 per acre as treble superphosphate (45%)

P_4 = 160 pounds of P_2O_5 per acre as treble superphosphate (45%)

P_5 = 200 pounds of P_2O_5 per acre as treble superphosphate (45%)

K_1 = 100 pounds of K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds of K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds of borax per acre (11.3% boron)

The maximum difference in yields per acre was 596 pounds. The lowest average yield of 3752 pounds of forage per acre was from the plots which received P_3B_1 treatment. The highest average yield of 4348 pounds of forage per acre was from P_3K_2B treatments. The overall average yield of all plots in the experiment was 4062 pounds per acre.

There were no statistically significant yield differences between the different phosphate treatments. The P_5 treatment gave the highest total average yield. The P_4 treatment gave the lowest total average yield.

The yield differences obtained for potassium fertilization were not statistically significant. The yield from the P_3 treatment increased with each increment of potassium added. However, the P_4 and P_5 treatments showed no response to potassium fertilization.

There was no apparent response to boron in this experiment.

Greenhouse Experiment

The greenhouse experiment was established to study the effects of the soil fertility treatments on the yield of alfalfa. The treatment symbols explained below will be used in the discussion of the results of the greenhouse experiment.

Treatment Symbol	Fertilizer Material	Analysis 1/	Rate lbs/A
Check	No Fertilizer		
P_1	Monocalciumphosphate	(0-55.4-0)	144.4
P_2	Monocalciumphosphate	(0-55.4-0)	288.8
K_1	Muriate of potash	(0-0-60)	333.2

K_2	Muriate of potash	(0-0-60)	666.4
B_1	Borax	(11.3%)	80.0

1/ Figures in parenthesis represent percent N - P_2O_5 - K_2O and B, respectively.

Yield data of alfalfa grown in the greenhouse are reported in Table VI. There were statistically significant yield differences between the fertility treatments as indicated by the F values from the analysis of variance. The yield figures discussed are the average of four replications and total of five cuttings reported as grams of oven dry forage per pot.

The maximum difference in average yields was 9.8 grams per pot. The lowest average yield of 20.9 grams was obtained from the K_2 treatment. The highest average yield of 30.7 grams was from the P_1K_2 treatment. The overall average was 25.17 grams per pot. The check pots produced more forage than the overall average of all treatments by .13 grams per pot.

The increase in yield due to phosphorus fertilization was significant at the five percent level. The application of phosphorus increased the overall phosphate yield average with each increment of phosphorus added. Neither the P_1 or P_2 treatment produced as much forage as did the check.

There were no statistically significant yield differences between potassium treatments as indicated by the F value from the analysis of variance. However, there was an increase in the overall average yield of the potash treatments with each increment of potassium added. Where potassium was added to the pots which received no phosphate, there was a decrease in yield. However, in most cases where phosphorus and potassium were added yields increased, which indicated the importance of

TABLE VI

EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS ON TOTAL YIELD OF ALFALFA HAY (OVEN DRY), NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, FIVE CUTTINGS, STILLWATER, 1959

Treatment Symbols 2/	Average Total Grams Per Pot 1/ B_0			B_1			
	K_0	K_1	K_2	K_0	K_1	K_2	$\bar{X}$
P_0	25.3	23.6	20.9	23.8	24.2	21.0	23.13
P_1	22.6	24.3	30.7	22.8	25.3	28.9	25.77
P_2	24.5	26.7	28.7	28.2	25.7	25.8	26.60
$\bar{X}$	24.13	24.86	26.76	24.93	25.06	25.23	25.17
$B_0B_1\bar{X}$		25.25			25.07		

1/ Yield figures are the mean of four replications. F values: P level 4.32*, K level <1 n.s., B level <1 n.s., Error mean square 17.9.

2/ Treatment symbols are:

$P_0B_0K_0$ = No treatment

P_1 = 40 pounds of P_2O_5 per acre as monocalcium phosphate (55.4%)

P_2 = 80 pounds of P_2O_5 per acre as monocalcium phosphate (55.4%)

K_1 = 100 pounds of K_2O per acre as muriate of potash (60%)

K_2 = 200 pounds of K_2O per acre as muriate of potash (60%)

B_1 = 40 pounds of borax per acre (11.3% boron)

* Significant at 5% level.

nutrient balance. There was P x K interaction as indicated by the F value from the analysis of variance.

The total yield of the boron treated pots was .18 grams less than that yield from non-boron treated pots. The 80 pound rate of borax per acre was apparently too high for this soil in the greenhouse experiment. Toxic effects on plant growth were observed on the foliage produced by the boron treated soil at each cutting.

V SUMMARY AND CONCLUSIONS

The objective of these experiments was to determine the effects of different fertilizer treatments on alfalfa yields. The field experiments were conducted on a Norge fine sandy loam near Stillwater, Oklahoma. The greenhouse experiment was also conducted on Norge fine sandy loam soil taken from an untreated area at the field experimental site.

Fertility treatments used in these studies included different rates of phosphorus, potassium and boron with all possible combinations of these treatments. Three alfalfa cuttings were obtained from the field experiments in 1958. Five cuttings were obtained from the greenhouse experiment in 1959.

Results from the field experiment may be summarized as follows:

1. In 1958, there was a highly significant yield increase with phosphorus fertilization on the low phosphate experiment. For the three year period during which the experiment was conducted, the yield increase due to phosphorus fertilization was significant at the five percent level.
2. There were no statistically significant yield differences obtained from the high phosphate experiment for 1958, or for the 1957 and 1958 average pooled yields.
3. The application of potassium in the low phosphate experiment gave a statistically significant yield increase at the five

percent level for 1958, and also for the average pooled yields for 1956, 1957 and 1958.

4. There was a yield increase with the application of borax on the low phosphate experiment; however, the increase was not statistically significant.

5. The highest total yield for 1958 was obtained from the plots receiving 80 pounds of P_2O_5 and 100 pounds of K_2O. The highest total yield from the three year period was obtained from plots receiving 80 pounds of P_2O_5, 100 pounds of K_2O and 40 pounds of borax.

The results from the greenhouse experiment may be summarized as follows:

1. There was a statistically significant response at the five percent level from the different phosphorus fertilizer treatments.

2. The addition of potassium fertilizer gave no statistical significant differences in forage yield.

3. There was an apparent interaction from the P x K combination, when analyzed statistically, at the five percent level.

4. Potassium alone appeared to have no effects on the yields of alfalfa in the greenhouse.

5. There were no statistically significant differences in yields obtained from the boron applications.

6. The highest average total yield was obtained from the pots receiving 80 pounds of phosphorus expressed as P_2O_5 and 400 pounds potassium expressed as K_2O per acre.

7. The 80 pound rate of borax per acre was apparently too high

for this soil in the greenhouse experiment.

Phosphorus was apparently the first limiting factor for improved yields of alfalfa on the soil used in these experiments. Yields increased with phosphorus fertilization up to 80 pounds of phosphorus, expressed as P_2O_5, applied per acre.

After this soil was fertilized with phosphorus, potassium became a limiting factor and yield increases were obtained with potassium fertilization.

Field plots that received both phosphorus and potassium fertilization gave additional increases in yield with borax fertilization. However, toxic effects were obtained when borax was applied at the rate of 80 pounds per acre in the greenhouse experiment.

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