EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON ALFALFA HAY AND SEED YIELDS

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I INTRODUCTION

Alfalfa is among the most important perennial forage crops produced in Oklahoma. Continued successful production of this legume is dependent on sound management and soil fertility practices adapted to each of the several soil and climatic areas within the state.

A soil fertility research study with alfalfa was initiated by the Oklahoma Agriculture Experiment Station in 1955. Results from these experiments have contributed information necessary for improved management and maintenance of alfalfa on important alfalfa producing soils in central and eastern Oklahoma.

The objective of these field and greenhouse studies was to determine the response of alfalfa to various soil fertility treatments. Treatments used in the field experiment at the Thomas farm included three rates of phosphorus, two rates of potassium and two rates of boron. Those treatments used at the Paradise farm included five rates of phosphorus, two rates of potassium and two rates of boron.

The greenhouse experiment was concerned with calcium and magnesium ratios applied with and without phosphorus and potassium fertilizers.

II REVIEW OF LITERATURE

Establishment and maintenance of alfalfa under Oklahoma soil and climatic conditions are dependent on successful management and soil fertility practices. Yields, hay quality and stand maintenance are greatly dependent in most areas on favorable soil conditions. Alfalfa has a high requirement for available plant nutrients from the soil (11)[1].

Lucas and Scarseth (18), with data from various plant sources converted the percentage of K, Ca and Mg to a chemical equivalent basis. A reciprocal relationship was found to prevail between the K, Ca and Mg in the plants. This relationship helps to account for the need of potassium in sorghum.

Schmehl et al. (34) studied the influence of soil acidity on the absorption of calcium by alfalfa, with radio-calcium. They reported the rate of absorption of calcium by alfalfa was markedly reduced in the presence of aluminum ions. It was reduced to a lesser degree in the presence of manganese and hydrogen ions of a nutrient solution. They suggested the low calcium content usually observed in plants grown in an acid soil may be due to the antagonistic effect of aluminum manganese and hydrogen ions on the absorption of calcium ions, rather than a low supply of calcium in the soil.

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[1] Figures in parenthesis refer to Literature Cited.

Winter survival of alfalfa is closely related to soil fertility. Wang (41) found that in most cases, the additions of lime or lime and other fertilizers, increased the water retention of alfalfa by increasing the water soluble protein content of the plants. This capacity for retention of water appears to be directly related to the ability of alfalfa to withstand winter killing.

Overliming of alfalfa is usually accompanied by reduced yields. According to Turk and Lynd (39), overliming not only reduces yields but it also reduces the percentage of potassium, manganese and phosphorus in the plants and increases the calcium content. In an investigation with legumes, Lynd and Turk (19) were able to prevent overliming injury by the application of manganese sulfate. They found a marked decrease in exchangeable manganese in the soil with increasing rates of lime. The quantity of exchangeable potassium and absorbed phosphorus was not appreciably affected.

Liming of alfalfa to optimum pH levels is closely related to yield. Moser (24) showed the calcium supplied at low pH values was a more important growth factor than the pH value. His results indicated that calcium supplied in increasing increments gradually increased in the plant, reaching the maximum where 10 m.e. of calcium was applied at a pH of 6.0 to 6.5.

Woodhouse (42) in North Carolina, concluded that the time and method of application of lime were more important than the rate of application. Best results were obtained by mixing the lime in the plow layer before planting. A high level of calcium depresses the uptake of magnesium and

potassium. It is typical of calcareous soil to require high levels of potassic fertilizers. This fact is well known on the thin chalk soils of southern and eastern England (32).

Alfalfa requires relatively large amounts of phosphorus. Only a part of the phosphorus fertilizer added to the soil as available phosphorus is used by the plant (25). Seay and Weeks (36), indicated that the best time for application of phosphate fertilizers was in the fall. They found that phosphorus was taken up by alfalfa during the dormant season. Nielson (30), indicated that the time of application of phosphate was not critical. Fall applications appeared to be equally as effective as spring applications. Woodhouse (43) found that young alfalfa plants have a high requirement for phosphorus.

Phosphate fertilizers on Washington soils were compared by Hausenbuiller and Weaver (14). They found that fertilizer phosphorus was neither leached from the soil nor reverted into an unavailable form. As a result, highly available phosphate carriers can be applied to alfalfa in amounts sufficiently large to last for several years.

Larson (17) found that yields of oats and alfalfa were markedly increased by phosphate fertilizer. The yields of the first two crops followed a curve of diminishing returns. Later, however, the first increment of 30 pounds of P_2O_5 per acre became ineffective. The first two years of the experiment, a corresponding increase in phosphorus and magnesium uptake was observed with phosphate applications, while the total uptake of calcium decreased. Hunter (15) concluded that the level of available phosphate in the soil was the most important factor affecting the phosphorus content of alfalfa.

MacLean and Cook (20) studied the effect of soil reaction on phosphorus availability. They found that liming to slightly above the neutral point increased the amount of available soil phosphorus.

Millar (23) reported that over 80 percent of the phosphorus applied to American soils in fertilizers is in forms designated as available, and from 5 to 15 percent of it is recovered in the first crop harvested after the application. The loss of available phosphates is due to the reversion of phosphorus from a soluble form to an insoluble form known as fixation. Murphy (26) has shown that phosphate fixation may occur in soils high in kaolin clay minerals. He believed this probably accounts for the phosphate that is fixed at about neutrality. However, the fixation power of most clay minerals is relatively low.

Seay (37) found a linear relationship in Wisconsin soils existed between the percentage of potassium contained in alfalfa and the logarithm of the number of pounds of exchangeable potassium in the soil on which the crop was grown. Brown (5) studied potassium and boron fertilization of alfalfa on some Connecticut soils. He reported that large applications of K_2O, before planting, produced alfalfa with a high potassium and low calcium content the first year.

It is well known by soil chemists that certain cations may be sorbed by the clay minerals in a nonexchangeable or a difficultly exchangeable state. Potassium is the most common ion that is "fixed" to any appreciable degree (12). Nelson and McEvoy (29) showed that an increase in yield and quality of tobacco was received when MgO was added to the soils that had a sufficient supply of available K_2O.

Chandler et al. (7) found the potassium content of alfalfa to be a reliable criterion for predicting the need of potassium fertilization. When the potassium content of the alfalfa plant at early bloom stage was less than 1.25 percent a profitable yield response usually resulted from fertilizer applications. When potassium content was over 1.25 percent, there was seldom any response to potassium fertilization. These workers proposed the critical level of the soil to be 80 pounds of exchangeable potassium per acre. Murphy (27) found that soil containing less than 60 P.P.M. of replaceable potassium generally responded to potassium fertilization if other factors were favorable for plant growth. Bear and Toth (1) found that alfalfa plants had the tendency to take up excess potassium at the expense of magnesium when excessive applications of potassium were made.

In many instances the trace elements are the first limiting plant growth factor. Boron has received considerable study in soil fertility experiments with alfalfa (2). The concentration range between the minimum amounts for plant growth and those which are toxic is relatively narrow. Stinson (38) found that the total boron content of alfalfa varied directly with the water soluble boron of the soil. Dible and Berger (9) reported that the level indicating a boron deficiency was approximately 9 P.P.M. Brown and King (6) decreased boron deficiency symptoms, increased height by 15 percent and yield by 16 percent with the 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 as compared with alfalfa that was not fertilized with boron. Murphy and Lynd (28) found increases in

yield of alfalfa hay in southeastern Oklahoma with the application of 32, 64 and 96 pounds P_2O_5 per acre. These phosphorus treatments combined with 72 pounds of K_2O gave larger increases over the respective P_2O_5 treatments alone. The addition of 40 pounds borax to the 0-64-72 treatment resulted in the highest yields in the experiment.

Manganese deficiencies commonly occur on soils of high pH and of high organic matter content (10). Lynd and Turk (19) found that with increasing rates of lime there was a marked decrease in exchangeable manganese. Garey and Barber (10) found evidence that oxidation of forms of sulfur or acid production were important for manganese to become available from unavailable forms. Varva and Fredrick (40) found that oxidation of elemental sulfur or sodium-thiosulfate applied to the soil resulted in a release of soluble manganese accompanied by a lowering of pH.

Many cultivated plants need comparatively large amounts of sulfur. In a humid climate the soil loses much sulfur through leaching. Bear (2) reported a marked increase in yields of crops, especially legumes, has been obtained by applications of sulfur fertilizers in many areas of the United States. He also pointed out that rainfall delivers between 5 and 30 pounds of sulfur per acre annually in most areas.

III MATERIALS AND METHODS

Field Experiments

A field experiment on a Port loam soil was located on the Thomas farm about $2\frac{1}{2}$ miles east of Stillwater in Payne County, Oklahoma, near State Highway 51 in the $NW\frac{1}{4}NW\frac{1}{4}$ sec. 20, Twp. 19 N., R. 3 E.

This soil was formed from material of alluvial origin and is located on an occasionally inundated floodplain. Port loam soil has a brown top soil about 16 inches in depth, which has a medium granular structure and friable consistence. It is underlain by calcareous, reddish-brown alluvial material. A detailed description of this soil series may be found in the Manual of Soil Series of Oklahoma (21). This field had been in continuous corn since 1948 and did not receive any lime during that period.

The plots on a Norge fine sandy loam soil were located on the Paradise farm, about 9 miles south and 7 miles west of Stillwater in Payne County, Oklahoma in the $SE\frac{1}{4}SE\frac{1}{4}$ sec. 34, Twp. 18 N., R. 1 E.

This soil was formed from material of old alluvial origin. Norge has a brown sandy loam topsoil about 8 inches in depth which has a weak fine granular structure and friable consistence accompanied by a few fine pores. It grades gradually to the layer below. A detailed description of this soil may be obtained from the Manual of Soil Series

of Oklahoma (21).

Experiments were started on an established stand of alfalfa in February of 1955 at the Thomas farm and in March of 1956 at Paradise farm. The annual applications of the treatments used were applied in the spring of 1957. These treatments included annual applications of the following at the Thomas and Paradise farms.

P_1 = 40 pounds P_2O_5 per acre as treble superphosphate (45%)
P_2 = 80 pounds P_2O_5 per acre as treble superphosphate (45%)
K_1 = 100 pounds K_2O per acre as KCl (60%)
K_2 = 200 pounds K_2O per acre as KCl (60%)
B = 40 pounds borax per acre (11.3% boron)

In addition, the Paradise experiment was expanded, which permitted studies with increased rates of phosphorus.

P_3 = 120 pounds P_2O_5 per acre as treble superphosphate (45%)
P_4 = 160 pounds P_2O_5 per acre as treble superphosphate (45%)
P_5 = 200 pounds P_2O_5 per acre as treble superphosphate (45%)
K_1 = 100 pounds K_2O per acre as KCl (60%)
K_2 = 200 pounds K_2O per acre as KCl (60%)
B = 40 pounds borax per acre (11.3% boron)

These plots were laid out in a split plot arrangement in a randomized block having all possible combinations of the above treatments with three replications.

Greenhouse Experiment

The objective of the greenhouse experiment was to determine the effects of calcium and magnesium ratios with and without potassium and phosphorus, and a combination of these elements, on the yield of alfalfa grown on a Norge fine sandy loam soil.

This soil was selected because it is a deep, well drained, permeable soil that will give high alfalfa yields with proper fertility practices and favorable moisture.

The soil was collected from the field, screened through a $\frac{1}{4}$-inch mesh screen and air dried. The containers being used in this experiment were two gallon, glazed, earthenware pots. Nine kilograms of soil were weighed into a sufficient number of pots to enable all treatments to be made in triplicate. Each of the 36 treatments were replicated making a total of 108 pots. All pots were adjusted to the same level of nitrogen as that supplied in 200 pounds of monoammonium phosphate. Monoammonium phosphate was selected as the phosphorus carrier to eliminate the application of calcium. The treatments were designated as follows:

Check	P_2	P_2K_1	K_1	P_1	P_1K_1
Ca_4	Ca_4P_2	$Ca_4P_2K_1$	Ca_4K_1	Ca_4P_1	$Ca_4P_1K_1$
Mg_4	Mg_4P_2	$Mg_4P_2K_1$	Mg_4K_1	Mg_4P_1	$Mg_4P_1K_1$
Ca_3Mg_1	$Ca_3Mg_1P_2$	$Ca_3Mg_1P_2K_1$	$Ca_3Mg_1K_1$	$Ca_3Mg_1P_1$	$Ca_3Mg_1P_1K_1$
Ca_2Mg_2	$Ca_2Mg_2P_2$	$Ca_2Mg_2P_2K_1$	$Ca_2Mg_2K_1$	$Ca_2Mg_2P_1$	$Ca_2Mg_2P_1K_1$
Ca_1Mg_3	$Ca_1Mg_3P_2$	$Ca_1Mg_3P_2K_1$	$Ca_1Mg_3K_1$	$Ca_1Mg_3P_1$	$Ca_1Mg_3P_1K_1$

Ca_4 = 10 ton $CaCO_3$ per acre (Tech.)
Mg_4 = 8.4 ton $MgCO_3$ per acre (C.P.)
Ca_3Mg_1 = 7.5 ton $CaCO_3$ and 2.1 ton $MgCO_3$ per acre
Ca_2Mg_2 = 5.0 ton $CaCO_3$ and 4.2 ton $MgCO_3$ per acre
Ca_1Mg_3 = 2.5 ton $CaCO_3$ and 6.3 ton $MgCO_3$ per acre
K_1 = 100 pounds K_2O per acre as KCl (C.P.)
P_1 = 100 pounds P_2O_5 per acre as monoammonium phosphate (C.P.)
P_2 = 200 pounds P_2O_5 per acre as monoammonium phosphate (C.P.)

All treatments were mixed thoroughly with the upper three inches of the soil. The approximate moisture equivalent value was determined. On this basis the soil was watered to its approximate field capacity before planting. Certified Buffalo alfalfa, Medicago sativa, was planted

September 23, 1957. The seed was treated with an inoculum, Rhizobium species, before planting. The plantings were made in circular bands within each pot and covered to a depth of $\frac{1}{2}$-inch. Following emergence, the number of plants was adjusted to 10 per pot.

The first, second and third cuttings were harvested February 28, April 8 and May 1, 1958 respectively. The plant material was dried in the oven at 65°C. and weighed.

All alfalfa hay yields were subjected to statistical analyses to aid in interpreting these data.

Physical and chemical properties of the soils used in the field experiment and greenhouse experiment are reported in Tables I and II respectively. Available phosphorus was determined by leaching with 0.1 normal acetic acid as proposed by Harper (13). Exchange capacity and exchangeable potassium were determined by the procedure presented by Jackson (16). Total nitrogen was determined by modification of the Kjeldahl method (32). 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 (4).

TABLE I

SOME PHYSICAL AND CHEMICAL CHARACTERISTICS
OF SOILS USED IN THE FIELD EXPERIMENTS

	Thomas farm Port loam	Paradise farm Norge fine sandy loam
Texture		
Percent sand	43.0	72.0
Percent silt	38.0	20.0
Percent clay	19.0	8.0
Reaction (pH)	5.0	6.6
Percent organic matter	1.42	1.00
Percent nitrogen	.077	.019
Available phosphorus (pounds per acre)	21.76	10.90
Exchangeable potassium (meq. per 100 gms.)	.24	.19
Cation exchange capacity (meq. per 100 gms.)	7.96	4.18

TABLE II

SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOIL USED IN THE GREENHOUSE EXPERIMENT

	Norge fine sandy loam
Texture	
Percent sand	72.0
Percent silt	20.0
Percent clay	8.0
Reaction (pH)	7.1
Percent organic matter	1.00
Percent nitrogen	.019
Available phosphorus (pounds per acre)	10.90
Exchangeable potassium (meq. per 100 gms.)	.19
Exchangeable calcium (meq. per 100 gms.)	1.30
Exchangeable magnesium (meq. per 100 gms.)	.33
Cation exchange capacity (meq. per 100 gms.)	4.18

IV RESULTS AND DISCUSSION

Greenhouse and field experiments were conducted to determine response of alfalfa to fertilization. Two soil types were studied in the field experiment, Port loam and Norge fine sandy loam, the latter was also used in the greenhouse experiment.

Field Experiment

Port loam: The 1957 growing season was very favorable for alfalfa production because of high rainfall. Four cuttings of hay were harvested. Total yields by cuttings with statistical results are summerized in Table III and the actual plot yields are shown in the appendix, Tables IX, X, XI and XII.

The maximum total yield of 11,289 pounds per acre was harvested from those plots receiving the P_1K_1F treatment. The lowest total mean yield of 9,358 pounds per acre was obtained from the P_2 treatment. The average total yield from the check (no fertilizer) treatment was 9,582 pounds per acre which is slightly above the lowest yielding plots.

There were no statistically significant yield differences between the treatments in the first cutting as indicated by the F value. The F value for potassium rates was significant at the 5% level for the second cutting. The phosphorus and potassium rates were both

TABLE III

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON TOTAL YIELD OF ALFALFA HAY, THOMAS FARM, PORT LOAM SOIL, 1957

Treatment 2/	Pounds 14% moisture hay at cutting date 1/ 5/29	7/6	8/13	9/28	Av. Total Yield
		Pounds per acre			
Check	3258	3513	1616	1195	9,582
P_1	3586	2999	1439	1352	9,376
P_2	3428	3173	1545	1212	9,358
K_1	3543	3233	1758	1162	9,696
P_1K_1	3913	3254	1991	1531	10,689
P_2K_1	3658	3488	2012	1595	10,753
K_2	3403	3394	1808	1205	9,810
P_1K_2	3509	3628	1978	1467	10,582
P_2K_2	3556	3424	2233	1450	10,663
B	3586	3428	1637	1127	9,778
P_1B	3956	2935	1535	1347	9,773
P_2B	3382	2935	1793	1283	9,393
K_1B	3573	3458	1723	1233	9,987
P_1K_1B	3977	3684	2105	1523	11,289
P_2K_1B	3552	3777	2152	1616	11,097
K_2B	3684	3764	1829	1184	10,461
P_1K_2B	3573	3301	1991	1429	10,294
P_2K_2B	3777	3479	2161	1616	11,033
Sm	4.41	5.76	3.02	1.69	4.16
C. V.	9.11%	12.53%	12.04%	9.14%	9.82%
F Value: Trt. 3/	1.04n.s.	1.12n.s.	3.45**	5.52**	3.14**
P level	n.s.	n.s.	5.92**	27.76**	n.s.
K level	n.s.	3.55*	17.95**	11.23**	15.90**
PxK level	n.s.	n.s.	n.s.	2.91*	n.s.

1/ Yield figures are the mean of three replications.

2/ Treatment symbols are:
Check = no fertilizer.
P_1 = 40 pounds P_2O_5 per acre as treble superphosphate (45%).
P_2 = 80 pounds P_2O_5 per acre as treble superphosphate (45%).
K_1 = 100 pounds K_2O per acre as KCl (60%).
K_2 = 200 pounds K_2O per acre as KCl (60%).
B = 40 pounds borax per acre (11.3%).

3/ * = Significant at 5% level.
** = Significant at 1% level.
n.s. = Not significant at 5% level.

significant at the 1% level in the third and fourth cuttings. The P x K interaction of the fourth cutting was significant at the 5% level.

Phosphorus treatments alone gave a slight decrease in yields as compared with the check (no fertilizer) treatment with a mean yield of 9,582 pounds per acre. The phosphorus treatments when in combination with the potassium treatments gave increases of more than a thousand pounds per acre in all cases over the check (no fertilizer) treatment.

When the effect of phosphorus and potassium treatments were combined with boron, yields in all cases were increased above those receiving phosphorus and potassium alone.

Potassium treatments indicated linear response in all combinations except the P_2K_1B treatment. The boron treatment gave a slight increase in yield over the no fertilizer treatment. Boron in combination with phosphorus and potassium also gave increased yields.

Norge fine sandy loam: Two experiments were conducted on this soil. Each experiment received the same rates of potassium and boron but had different rates of phosphorus applied. One area is referred to as the low phosphorus area, which had the check (no fertilizer) treatment and two phosphorus rates of 40 and 80 pounds P_2O_5 per acre. The other area is referred to as the high phosphorus area and received 120, 160 and 200 pounds of P_2O_5 per acre.

Four alfalfa hay cuttings and one seed crop were taken from this experiment in 1957.

The hay and seed yields for the low phosphate level with the statistical results are summarized in Tables IV and V respectively.

TABLE IV

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVELS ON TOTAL YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, 1957

Treatment 2/	Pounds 14% moisture hay at cutting date 1/ 5/16	6/20	7/20	10/18	Av. Total Yield
		Pounds per acre			
Check	2310	2088	1471	919	6788
P_1	2488	2148	1531	876	7043
P_2	2595	1982	1361	1076	7014
K_1	2429	2212	1671	914	7226
P_1K_1	2488	2155	1642	961	7246
P_2K_1	2544	2233	1642	1182	7601
K_2	2352	2203	1663	876	7094
P_1K_2	2650	2246	1599	957	7452
P_2K_2	2471	2012	1510	1004	6997
B	2339	2394	1425	961	7119
P_1B	2488	2297	1395	982	7162
P_2B	2514	2024	1523	970	7031
K_1B	2535	2322	1629	900	7386
P_1K_1B	2735	2195	1663	1174	7767
P_2K_1B	2629	2246	1765	1297	7937
K_2B	2403	2233	1714	897	7247
P_1K_2B	2684	1961	1523	991	7159
P_2K_2B	2735	2288	1650	1161	7834
Sm	2.87	3.13	2.60	2.40	4.16
C. V.	8.82%	9.74%	12.18%	17.58%	9.82%
F Value: Trt. 3/	1.09n.s.	0.84n.s.	1.06n.s.	1.42n.s.	1.63n.s.
P level	4.66*	n.s.	n.s.	6.02**	n.s.
K level	n.s.	n.s.	6.23**	n.s.	4.99*

1/ Yield figures are the mean of three replications.

2/ Treatment symbols are:
Check = no fertilizer.
P_1 = 40 pounds P_2O_5 per acre as treble superphosphate (45%).
P_2 = 80 pounds P_2O_5 per acre as treble superphosphate (45%).
K_1 = 100 pounds K_2O per acre as KCl (60%).
K_2 = 200 pounds K_2O per acre as KCl (60%).
B = 40 pounds borax per acre (11.3%).

3/ * = Significant at 5% level.
** = Significant at 1% level.
n.s. = not significant at 5% level.

TABLE V

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVELS ON YIELD OF ALFALFA SEED, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, SEPTEMBER 6, 1957

Treatment 1/	Pounds of seed per acre Rep 1	Rep 2	Rep 3	Av. Total Yield
Check	125	98	68	97.0
P_1	70	80	91	80.3
P_2	104	66	92	87.3
K_1	99	109	45	84.3
P_1K_1	108	93	105	102.0
P_2K_1	160	48	98	102.0
K_2	57	51	21	43.0
P_2K_2	72	52	33	52.3
P_1K_2	46	148	51	48.3
B	61	87	108	85.3
P_1B	111	92	87	96.6
P_2B	81	79	53	71.0
K_1B	103	122	61	95.3
P_1K_1B	109	113	60	94.0
P_2K_1B	123	130	79	110.7
K_2B	127	83	52	87.3
P_2K_2B	87	111	63	87.0
P_1K_2B	103	128	102	111.0

Treatment F = 1.370 n.s.
Standard Error of Mean = 4.80
Coefficient of Variation = 3.53%
1/ See Table IV for details of treatments.
n.s. = Not significant at 5% level.

The hay and seed yields for the high phosphate levels with statistical results are summarized in Tables VI and VII. Actual plot yields of the low phosphate area are shown in appendix Tables XIII, XIV, XV and XVI with the actual plot yields from the high phosphate levels shown in appendix Tables XVII, XVIII, XIX and XX.

Low phosphate levels for alfalfa forage: Lowest total mean yield of alfalfa hay, 6,788 pounds per acre was obtained from the check (no fertilizer) treatment. Highest average total yield, 7,937 pounds per acre was obtained from the P_2K_1B treatment.

Statistically significant differences were obtained on the phosphorus level with the first cutting as indicated by the F value. There were no statistical differences between the treatments in the second cutting. The potassium treatments gave yields different significantly at the 1% level in the third cutting and yields from the phosphorus treatments were significantly different at the 1% level in the fourth cutting. The only significances in the average total yield was at the 5% level as a function of potassium treatment.

Low phosphate levels for seed: Yields of alfalfa seed from the field experimental plots that received the low phosphorus treatments are summarized in Table V. Lowest yields of 43.0 pounds per acre were obtained from the K_2 treatments. The highest yields of 111.0 pounds per acre were obtained from the P_2K_2B treatments and the P_2K_1B treatments with an average yield of 110.7 pounds per acre.

The check (no fertilizer) treatments gave yields of 97.0 pounds per acre which was exceeded by only four treatments. These treatments

were P_2K_2B, P_2K_1B, P_1K_1 and P_2K_1.

High phosphate levels for alfalfa forage: The lowest total yield, 5,702 pounds per acre was obtained from the P_3B treatments. Highest total yield, 6,908 pounds per acre was obtained from the P_3K_2B treatments.

Statistically significant differences were obtained at the 5% level for the first cutting on the P treatments and the P x K and K x B interactions with significance at the 1% level on the P x K x B interactions. The second cutting had no significance except at the 5% level on the P x K x B interactions. The third cutting showed no significant differences in yield with any treatment. Significance in yield difference was shown at the 5% level on the K treatment and at the 1% level on the P x K treatments for the fourth cutting. The only significant difference in the average total yield was at the 5% level on P x K treatments.

The phosphorus treatments alone appeared to give linear response. The P_3K_1, P_3K_2, P_4K_1 and P_4K_2 treatment combinations gave increased yields over the P_3 and P_4 treatments. However, the P_5K_1 and P_5K_2 treatments gave lower yield than P_5 treatment alone. Increases were also noted for the boron treatments over the phosphorus alone and phosphorus and potassium combinations.

Seed yields for the high phosphorus levels: Yields of alfalfa seed from the field experimental plots that received the high phosphorus treatments are summarized in Table VII. Lowest yields of 55.6 pounds of seed per acre was obtained from the P_4 treatments. The highest yield, 123.3 pounds of seed per acre was obtained from the P_5B plot treatments. Boron with three rates of phosphorus alone, gave higher yields than any of the

TABLE VI

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVELS ON TOTAL YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, 1957

Treatment 2/	Pounds 14% moisture hay at cutting date 1/ 5/16	6/20	7/20	10/18	Av. Total Yield
		Pounds per acre			
P_3	1765	2054	1148	821	5788
P_4	2197	1914	1046	851	6008
P_5	2382	2216	1216	914	6728
P_3K_1	2233	2233	1267	893	6626
P_4K_1	2382	1727	1161	842	6112
P_5K_1	2254	2020	1182	714	6170
P_3K_2	2140	1948	1255	1054	6397
P_4K_2	2169	1982	1238	757	6146
P_5K_2	2254	2110	1204	918	6486
P_3B	1921	1884	1127	770	5702
P_4B	2205	1978	1212	927	6322
P_5B	2233	2033	1289	876	6431
P_3K_1B	2212	1884	1140	786	6022
P_4K_1B	2389	1914	1255	918	6476
P_5K_1B	2205	2076	1233	863	6377
P_3K_2B	2297	2280	1255	1076	6908
P_4K_2B	2212	1701	1148	893	5954
P_5K_2B	2332	1927	1140	936	6335
S_m	.503	2.91	1.79	1.61	2.66
C. V.	5.24%	10.77%	11.03%	13.49%	6.21%
F Value: Trt. 3/	4.23**	1.52n.s.	0.67n.s.	1.85n.s.	1.67n.s.
P level	4.66*	4.42*	n.s.	n.s.	n.s.
K level	n.s.	n.s.	n.s.	3.70*	n.s.
PxK level	3.62*	n.s.	n.s.	3.98**	2.85*
KxB level	4.30*	n.s.	n.s.	n.s.	n.s.
PxKxB level	8.20**	3.03*	n.s.	n.s.	n.s.

1/ Yield figures are the mean of three replications.

2/ Treatment symbols are:
- P_3 = 120 pounds P_2O_5 per acre as treble superphosphate (45%).
- P_4 = 160 pounds P_2O_5 per acre as treble superphosphate (45%).
- P_5 = 200 pounds P_2O_5 per acre as treble superphosphate (45%).
- K_1 = 100 pounds K_2O per acre as KCl (60%).
- K_2 = 200 pounds K_2O per acre as KCl (60%).
- B = 40 pounds borax per acre (11.3%).

3/ * = Significant at 5% level.
** = Significant at 1% level.
n.s. = Not significant at 5% level.

TABLE VII

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVELS ON YIELD OF ALFALFA SEED, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, SEPTEMBER 6, 1957

Treatment 1/	Pounds of seed per acre Rep 1	Rep 2	Rep 3	Av. Total Yield
P_3	87	106	55	82.6
P_4	57	67	73	65.6
P_5	127	149	79	118.3
P_3K_1	47	106	112	88.3
P_4K_1	53	102	93	82.6
P_5K_1	65	74	87	75.3
P_3K_2	112	125	96	111.0
P_4K_2	106	95	122	107.6
P_5K_2	96	107	101	101.3
P_3B	80	98	105	94.3
P_4B	89	118	94	100.3
P_5B	147	120	103	123.3
P_3K_1B	82	95	102	93.0
P_4K_1B	110	107	130	115.6
P_5K_1B	84	100	76	86.6
P_3K_2B	83	102	86	90.3
P_4K_2B	73	88	84	81.6
P_5K_2B	66	70	90	75.3

F Values: Treatment = 2.601**
PxK level = 5.130**
PxKxB level = 4.449**
Standard Error of Mean = 10.09
Coefficient of Variation = 18.56%
**Significant at 1% level.
1/ See Table VI for details of treatments.

boron, phosphorus and potassium combinations. Potassium application at the K_2 treatment level with three rates of phosphorus gave higher increases than the K_1 treatment plus three rates of phosphorus. These data indicate the need for nutrient element balance for seed production with a high rate of fertilizer application.

Greenhouse Experiment

Norge fine sandy loam: Three cuttings of alfalfa forage were obtained from this experiment. Total yields and results of the statistical analysis by treatments are shown in Table VIII. Forage yields by cuttings with statistical analysis of yields are shown in appendix Table XXI.

The pots receiving the Mg_4K_1 treatments produced the highest total yield, 13.52 grams. The lowest total yield of 10.26 grams per pot was obtained from the check treatments (no differential fertilization). An apparent linear type response was noted with decreasing amounts of calcium and increasing amounts of magnesium as indicated by the average of the calcium and magnesium treatments. Blalock (3) worked with alfalfa on a Waynesboro soil in the greenhouse. He found that plant growth was inhibited with the application of 8.4 tons of $MgCo_3$ per acre. The 8.4 tons of $MgCo_3$ per acre, on the Port loam soil gave the highest average yield of 12.91 grams which is higher than calcium alone or combined calcium and magnesium treatments.

The mean yield of the P_1K_1 treatments with all combinations of calcium and magnesium was higher than the P_2K_1 treatments with the same calcium and magnesium combinations.

The addition of phosphorus at both the P_1 and P_2 levels increased

TABLE VIII

TOTAL YIELD OF ALFALFA FORAGE AS AFFECTED BY VARIOUS SOIL FERTILITY TREATMENTS, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, THREE CUTTINGS, STILLWATER, 1958

Treatment 1/	Check	Ca_4	Ca_3Mg_1	Ca_2Mg_2	Ca_1Mg_3	Mg_4	Av.
			Grams oven dry forage 2/				
Check	10.26	11.88	10.30	11.45	12.25	11.88	11.34
P_1	12.66	11.33	12.29	10.93	12.82	13.49	12.25
K_1	12.03	11.82	11.19	12.19	11.21	13.52	11.99
P_1K_1	11.62	12.13	12.12	13.40	13.16	13.40	12.64
P_2	11.59	11.45	11.39	13.03	12.86	13.06	12.23
P_2K_1	10.86	10.95	11.79	12.36	12.52	12.12	11.77
Av.	11.50	11.59	11.51	12.23	12.47	12.91	12.03

Standard Error of Mean = .351
Treatment F Value = 1.90*
Coefficient of Variation = 8.76%

1/ Soil fertility treatments were as follows:
Check = No differential fertility treatments.
Ca_4 = 10 ton $CaCO_3$ per acre (Tech.)
Mg_4 = 8.4 ton $MgCO_3$ per acre.
Ca_3Mg_1 = 7.5 ton $CaCO_3$ and 2.1 ton $MgCO_3$ per acre.
Ca_2Mg_2 = 5.0 ton $CaCO_3$ and 4.2 ton $MgCO_3$ per acre.
Ca_1Mg_3 = 2.5 ton $CaCO_3$ and 6.3 ton $MgCO_3$ per acre.
K_1 = 100 pounds K_2O per acre as KCl (C.P.)
P_1 = 100 pounds P_2O_5 per acre as monoammonium phosphate.
P_2 = 200 pounds P_2O_5 per acre as monoammonium phosphate.
All pots received $CO(NH_2)_2$ in an amount to supply equivalent nitrogen supplied by 200 lbs./A of monoammonium phosphate.

2/ Yield figures represent the mean of three replicate pots.

* Significant at 5% level.

the total average yield over the check. It was also noted that when potassium was applied, the total average yield exceeded the check. The check, K_1 and P_2K_1, gave average total yields less than the overall mean of 12.03 grams per pot.

V SUMMARY AND CONCLUSIONS

The objective of the field and greenhouse experiment was to determine the differential response of alfalfa seed and forage yield to various soil fertility treatments. Field experiments were conducted at two locations near Stillwater, Oklahoma, on Port loam and Norge fine sandy loam. A greenhouse study was conducted using a Norge fine sandy loam soil.

The field experimental studies included different rates of phosphorus and potassium fertilization with and without boron. Four alfalfa hay cuttings were obtained from both field experiments.

Field experimental results indicated the following:

1. Alfalfa yields were significantly increased by potassium fertilization on all but one cutting on the Port loam soil.

2. Yield increases were obtained with the application of boron with the highest yield obtained from the application of 40 pounds of borax per acre in combination with 40 pounds P_2O_5 and 100 pounds K_2O per acre on the Port loam soil.

3. The mean total yields of alfalfa forage from all cuttings were significantly increased with potassium fertilization in combination with the low phosphate treatments on the Norge fine sandy loam soil.

4. The highest average total yield was obtained from the treatment combinations of 100 pounds K_2O, 80 pounds P_2O_5 and 40 pounds borax applied per acre on the Norge fine sandy loam soil from the low phosphate level experiment.

5. Differences in the average seed yields were not significantly affected by soil fertility treatments at the 5% level. The highest average alfalfa seed yield was obtained from 80 pounds P_2O_5, 200 pounds K_2O and 40 pounds borax applied per acre with the low phosphate treatments on the Norge fine sandy loam.

6. Significance was found for the P x K interaction on the average total yield of alfalfa forage in the high phosphate rate experiment. Differences between average yields of alfalfa hay as affected by various soil fertility treatments were not significant at the 5% level with the high phosphate fertilization treatments. Highest average yields were obtained from 120 pounds P_2O_5, 200 pounds K_2O and 40 pounds borax per acre with the high phosphate fertilization experiment on the Norge fine sandy loam soil.

7. Boron and phosphorus combinations gave higher alfalfa seed yields than did boron, phosphorus and potassium combinations on the Norge fine sandy loam soil, with the higher phosphate levels.

The greenhouse experiment was conducted to determine the effects of calcium and magnesium ratios with and without potassium and phosphorus fertilization on yield of alfalfa forage. Three cuttings were obtained from this experiment.

Greenhouse experimental results are summarized as follows:

1. A linear type increase in alfalfa yield was indicated on the Norge fine sandy loam with increasing amounts of magnesium, up to 8.4 tons $MgCO_3$ per acre combined with decreasing amounts of calcium. Alfalfa yields were significantly affected by fertility treatments. The highest average total yield was obtained from the 8.4 ton of $MgCO_3$ and 100 pounds K_2O per acre treatment.

2. No consistent yield response to the three different rates of phosphorus and two rates of potassium fertilization alone and in combination was apparent with the various calcium and magnesium treatments applied to the Norge fine sandy loam soil.

VI LITERATURE CITED

1. Bear, F. E. and S. J. Toth. Influence of calcium on availability of other soil cations. Soil Sci. 65:69-74. 1948.

2. _____. Soils and Fertilizers. Fourth Edition. New York, John Wiley and Sons, Inc. 1951.

3. Blalock, J. H. Effect of various soil fertility treatments on alfalfa yield and composition with emphasis on calcium and magnesium ratios. Unpublished Master of Science Thesis, Oklahoma State University. 1957.

4. Bouyoucos, George J. Directions for making mechanical analysis of soil by the hydrometer method. Soil Sci. 42:225-229. 1936.

5. Brown, B. A., I. R. Munsell and A. King. Potassium and boron fertilization of alfalfa on a few Connecticut soils. Soil Sci. Soc. Amer. Proc. 10:134-140. 1945.

6. _____ and A. King. Soil conditions under which alfalfa responded to boron. Soil Sci. Soc. Amer. Proc. 4:310-313. 1939.

7. Chandler, R. F., M. Peech and R. Bradfield. A study of the techniques for predicting the potassium and boron requirements of alfalfa: I. The influence of potash and borax on yield, deficiency symptoms and the boron content of plants and soil. Soil Sci. Soc. Amer. Proc. 10:141-146. 1945.

8. Dennis, E. J. and L. Chesnin. The availability of phosphorus to alfalfa in the horizons of four eastern Nebraska soils. Soil Sci. Soc. Amer. Proc. 17:49-52. 1953.

9. Dible, W. T. and K. C. Berger. Boron content of alfalfa as influenced by boron supply. Soil Sci. Soc. Amer. Proc. 16: 60-62. 1952.

10. Garey, C. L. and S. A. Barber. Evaluation of certain factors involved in increased manganese availability with sulfur. Soil Sci. Soc. Amer. Proc. 16:173-175. 1952.

11. Graumann, H. O. and C. H. Hanson. Growing alfalfa. U.S.D.A. Farmers Bulletin No. 1722. 1954.

12. Grim, R. E. Clay minerology. McGraw-Hill Book Company, Inc., p. 152. 1953.

13. Harper, H. J. Determination of the easily soluble phosphorus in soils. Soil Sci. 76:415-416. 1932.

14. Hausenbuiller, R. L. and W. H. Weaver. A comparison of phosphate fertilizers for alfalfa on irrigated central Washington soils. Sta. Cir. 257, Wash. Agri. Exp. Sta., Pullman, Washington. 1954.

15. Hunter, A. S. Yield and composition of alfalfa as affected by variations in the calcium magnesium ratio in the soil. Soil Sci. 67:53-62. 1949.

16. Jackson, M. L. Soil Chemical Analysis, Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 1958.

17. Larson, W. E., L. B. Nelson and A. S. Hunter. The effects of phosphate fertilization upon the yield and composition of oats and alfalfa grown on phosphate deficient Iowa soils. Agron. Jour. 44:357-361. 1952.

18. Lucas, R. C. and G. D. Scarseth. Potassium, calcium and magnesium balance and reciprocal realtionship in plants. Jour. Amer. Soc. Agron. 39:887-896. 1947.

19. Lynd, J. Q. and L. M. Turk. Overliming injury on an acid sandy soil. Jour. Amer. Soc. Agron. 40:205-215. 1948.

20. MacLean, A. J. and R. L. Cook. The effect of soil reaction on availability of phosphorus for alfalfa in some eastern Ontario soils. Soil Sci. Soc. Amer. Proc. 19:311-314. 1955.

21. Manual of Soil Series of Oklahoma. Division of Soil Survey, Bureau of Plant Industry, Soils and Agriculture Engineering, Agricultural Research Administration, U.S.D.A.

22. Methods of Analysis. Association of Official Agricultural Chemists. Sixth Edition. pp. 14-16. 1945.

23. Millar, C. E. Soil Fertility, John Wiley and Sons, Inc., New York. p. 152. 1955.

24. Moser, F. Calcium nutrition at respective pH levels. Soil Sci. Soc. Amer. Proc. 7:339-344. 1942.

25. _____. Fixation and recovery of phosphate from lateritic soils. Soil Sci. Soc. Amer. Proc. 6:328-334. 1941.

26. Murphy, H. F. Clay minerals and phosphate availability. Proc. Okla. Acad. Sci. 20:68. 1940.

27. _____. The replaceable potassium content comparable with field response to potash fertilization of some Oklahoma soils. Jour. Amer. Soc. Agron. 28:34-37. 1934.

28. _____ and J. Q. Lynd. Effects of various soil fertility treatments on alfalfa production in southeastern Oklahoma. Soil Sci. Soc. Amer. Proc. 20-385-387. 1956.

29. Nelson, N. T. and E. T. McEvoy. Use of potash in tobacco production. C. A. 40:2571. 1946.

30. Nielson, R. Phosphate fertilizer increases alfalfa hay yields. Utah Agri. Exp. Sta. Farm and Home Sci. 13:14-15. 1952.

31. Peech, M. and L. English. Rapid microchemical soil tests. Soil Sci. 57:167-195. 1944.

32. Piper, C. S. Soil and Plant Analysis. Interscience Publishers, Inc., New York, New York. 1950.

33. Russell, J. E. Soil conditions and plant growth. Longmans, Green and Co., New York.

34. Schmehl, W. E., M. Peech and R. Bradfield. The influence of soil acidity on absorption of calcium by alfalfa as revealed by radio calcium. Soil Sci. 73:11-21. 1952.

35. Schollenberger, C. J. A rapid approximate method for the determination of soil organic matter. Soil Sci. 24: 65-68. 1927.

36. Seay, W. A. and M. E. Weeks. The effect of time of top-dressing on uptake of phosphorus and potassium by an established stand of alfalfa. Soil Sci. Soc. Amer. Proc. 19:458-461. 1955.

37. _____, O. J. Altoe and E. Truog. Correlation of the potassium content of alfalfa with that available in soils. Soil Sci. Soc. Amer. Proc. 14:245-249. 1950.

38. Stinson, C. H. Relation of water soluble boron in Illinois soils to boron content of alfalfa. Soil Sci. 75:31-36. 1953.

39. Turk, L. M. and J. Q. Lynd. Too much lime may be harmful. "What's New in Crops and Soils". 1:(3) 10-11. 1948.

40. Varva, J. P. and L. R. Fredrick. The effect of sulfur oxidation on the availability of manganese. Soil Sci. Soc. Amer. Proc. 16:141-144. 1952.

41. Wang, L. C., O. J. Attoe and E. Truog. Effects of lime and fertility levels on the chemical composition and winter survival of alfalfa. Agron. Jour. 45:381-384. 1953.

42. Woodhouse, W. W., Jr. Effects of placement and rates of phosphate, potash and limestone on the growth of alfalfa and lespedeza. Soil Sci. Soc. Amer. Proc. 20:15-18. 1956.

43. _____. Fertilizing alfalfa. Research and Farming 9:19-21. 1950.

VII APPENDIX

TABLE IX

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, FIRST CUTTING, MAY 29, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	76.0	76.0	78.0	230.0
P_1	88.0	74.0	91.0	253.0
P_2	73.5	78.0	90.5	242.0
K_1	81.0	87.0	82.0	250.0
P_1K_1	103.0	90.5	82.5	276.0
P_2K_1	93.5	78.0	86.5	258.0
K_2	96.5	84.0	83.5	264.0
P_1K_2	77.0	80.5	90.0	247.5
P_2K_2	82.5	83.5	85.0	251.0
B	93.0	78.0	82.0	253.0
P_1B	102.5	82.5	94.0	279.0
P_2B	76.5	86.0	76.0	238.5
K_1B	88.0	82.5	81.5	252.0
P_1K_1B	102.5	95.5	82.5	280.5
P_2K_1B	83.0	86.0	81.5	250.5
K_2B	91.5	82.5	86.0	260.0
P_1K_2B	72.5	95.5	84.0	252.0
P_2K_2B	92.5	96.5	77.5	266.5

1/ See Table III for details of treatments and statistical results.

TABLE X

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, SECOND CUTTING, JULY 6, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	91.5	85.5	71.0	248.0
P_1	68.0	86.0	57.5	211.5
P_2	100.0	63.0	61.0	224.0
K_1	75.0	83.0	70.0	228.0
P_1K_1	78.5	83.5	67.5	229.5
P_2K_1	91.0	70.5	84.5	246.0
K_2	81.0	78.0	80.5	239.5
P_1K_2	84.5	81.0	90.5	256.0
P_2K_2	80.5	86.5	74.5	241.5
B	68.0	90.0	84.0	242.0
P_1B	75.0	47.0	85.0	207.0
P_2B	64.5	71.5	71.0	207.0
K_1B	78.0	94.5	71.5	244.0
P_1K_1B	79.5	87.5	93.0	260.0
P_2K_1B	80.0	97.0	89.5	266.5
K_2B	90.5	90.5	84.5	265.5
P_1K_2B	84.5	76.5	72.0	233.0
P_2K_2B	77.5	89.5	78.5	245.5

1/ See Table III for details of treatments and statistical results.

TABLE XI

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, THIRD CUTTING AUGUST 13, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	42.0	41.0	31.0	114.0
P_1	34.0	31.0	36.5	101.5
P_2	39.5	35.0	34.5	109.0
K_1	44.5	46.0	33.5	124.0
P_1K_1	33.0	47.5	60.0	140.5
P_2K_1	49.5	46.0	46.5	142.0
K_2	46.5	44.0	37.0	127.5
P_1K_2	51.5	44.5	43.5	139.5
P_2K_2	52.0	62.0	43.5	157.5
B	35.0	44.0	36.5	115.5
P_1B	38.5	31.0	39.0	108.5
P_2B	49.0	40.5	37.0	126.5
K_1B	36.5	46.5	38.5	121.5
P_1K_1B	50.5	47.0	51.0	148.5
P_2K_1B	54.5	49.0	48.5	152.0
K_2B	41.0	44.5	38.5	129.0
P_1K_2B	55.0	44.0	41.5	140.5
P_2K_2B	57.0	51.5	44.0	152.5

1/ See Table III for details of treatments and statistical results.

TABLE XII

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, FOURTH CUTTING, SEPTEMBER 28, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	27.5	32.0	25.0	84.5
P_1	31.0	35.5	29.0	95.5
P_2	34.5	26.5	24.5	85.5
K_1	28.0	27.0	27.0	82.0
P_1K_1	34.0	40.0	34.0	108.0
P_2K_1	39.0	38.5	35.0	112.5
K_2	30.0	28.5	26.5	85.0
P_1K_2	34.5	36.0	33.0	103.5
P_2K_2	40.5	33.5	28.5	102.5
B	28.0	27.5	24.0	79.5
P_1B	35.5	31.5	28.0	95.0
P_2B	34.5	27.5	28.5	90.5
K_1B	27.5	32.5	27.0	87.0
P_1K_1B	35.5	34.0	38.0	107.5
P_2K_1B	40.5	36.5	37.0	114.0
K_2B	32.5	30.5	20.5	83.5
P_1K_2B	35.5	36.0	29.5	101.0
P_2K_2B	37.0	44.0	33.0	114.0

1/ See Table III for details of treatments and statistical results.

TABLE XIII

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, FIRST CUTTING, MAY 16, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	44.5	59.5	59.0	163.0
P_1	53.5	63.5	58.5	175.5
P_2	59.5	67.0	56.5	183.0
K_1	52.0	55.5	64.0	171.5
P_1K_1	54.0	64.5	57.0	175.5
P_2K_1	60.5	54.5	64.5	179.5
K_2	55.0	61.0	50.0	166.0
P_1K_2	59.5	61.0	63.5	184.0
P_2K_2	60.0	56.0	58.5	174.5
B	46.0	58.0	61.0	165.0
P_1B	51.5	69.0	55.0	175.5
P_2B	55.0	67.5	55.0	177.5
K_1B	57.0	65.0	57.0	179.0
P_1K_1B	62.0	64.5	66.5	193.0
P_2K_1B	63.0	56.5	66.0	185.5
K_2B	60.0	60.0	49.5	169.5
P_1K_2B	61.0	64.5	64.0	189.5
P_2K_2B	62.0	67.5	63.5	193.0

1/ See Table IV for details of treatments and statistical results.

TABLE XIV

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, SECOND CUTTING, JUNE 20, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	46.0	51.5	50.0	147.5
P_1	47.0	52.5	52.0	151.5
P_2	35.5	49.5	55.0	140.0
K_1	53.5	52.0	50.5	156.0
P_1K_1	50.5	54.5	47.0	152.0
P_2K_1	49.0	56.0	52.5	157.5
K_2	61.5	49.0	45.0	155.5
P_1K_2	57.0	56.5	45.0	158.5
P_2K_2	50.0	45.5	46.5	142.0
B	53.5	59.0	56.5	169.0
P_1B	55.0	59.5	47.5	162.0
P_2B	43.5	50.5	49.0	143.0
K_1B	59.5	54.0	50.5	164.0
P_1K_1B	51.0	54.0	50.0	155.0
P_2K_1B	48.0	51.5	59.0	158.5
K_2B	51.0	53.5	53.0	157.5
P_1K_2B	45.5	57.0	36.0	138.5
P_2K_2B	59.5	55.5	46.5	161.5

1/ See Table IV for details of treatments and statistical results.

TABLE XV

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, THIRD CUTTING, JULY 20, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	33.5	40.5	30.0	104.0
P_1	31.5	44.5	32.0	108.0
P_2	31.5	30.0	34.5	96.0
K_1	42.0	44.0	34.0	118.0
P_1K_1	36.5	48.5	31.0	116.0
P_2K_1	40.0	39.0	37.0	116.0
K_2	44.5	37.0	36.0	117.5
P_1K_2	39.0	44.5	29.5	113.0
P_2K_2	42.0	32.0	32.5	106.5
B	33.0	40.5	27.0	100.5
P_1B	33.0	32.0	33.5	98.5
P_2B	35.0	37.0	35.5	107.5
K_1B	41.0	44.0	30.0	115.0
P_1K_1B	38.0	45.5	34.0	117.5
P_2K_1B	36.5	43.5	44.5	124.5
K_2B	45.5	39.0	36.5	121.0
P_1K_2B	39.0	39.5	29.0	107.5
P_2K_2B	43.5	37.0	36.0	116.5

1/ See Table IV for details of treatments and statistical results.

TABLE XVI

EFFECT OF VARIOUS SOIL-FERTILITY TREATMENTS WITH THE LOW PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, FOURTH CUTTING, OCTOBER 18, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	21.0	23.5	20.5	65.0
P_1	17.5	21.5	23.0	62.0
P_2	27.5	18.5	30.0	76.0
K_1	21.0	26.5	17.0	64.5
P_1K_1	19.5	23.5	25.0	68.0
P_2K_1	28.0	24.5	31.0	83.5
K_2	24.0	19.5	18.5	62.0
P_1K_2	20.5	29.0	18.0	67.5
P_2K_2	30.0	24.5	16.5	71.0
B	21.0	25.0	22.0	68.0
P_1B	24.0	22.5	23.0	69.5
P_2B	24.5	21.0	23.0	68.5
K_1B	19.0	27.0	17.5	63.5
P_1K_1B	20.0	33.5	29.5	83.0
P_2K_1B	32.0	30.0	29.5	91.5
K_2B	21.0	23.5	19.0	63.5
P_1K_2B	19.0	31.5	19.5	70.0
P_2K_2B	23.0	31.0	28.0	82.0

1/ See Table IV for details of treatments and statistical results.

TABLE XVII

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, FIRST CUTTING, MAY 16, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
P_3	54.0	54.5	46.0	154.5
P_4	52.5	54.5	48.0	155.0
P_5	54.0	59.0	55.0	168.0
P_3K_1	51.5	52.5	53.5	157.5
P_4K_1	62.0	52.0	54.0	168.0
P_5K_1	56.0	52.5	50.5	159.0
P_3K_2	57.0	46.0	48.0	151.0
P_4K_2	50.0	52.5	50.5	153.0
P_5K_2	57.0	49.0	53.0	159.0
P_3B	43.0	49.5	43.0	135.5
P_4B	52.5	56.0	47.0	155.5
P_5B	56.5	47.5	53.5	157.5
P_3K_1B	55.0	52.5	48.5	156.0
P_4K_1B	59.5	55.0	54.0	168.5
P_5K_1B	53.5	53.0	49.0	155.5
P_3K_2B	65.5	46.0	50.5	162.0
P_4K_2B	59.5	47.5	49.0	156.0
P_5K_2B	56.0	53.5	55.0	164.5

1/ See Table VI for details of treatments and statistical results.

TABLE XVIII

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, SECOND CUTTING, JUNE 20, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
P_3	46.0	48.0	51.0	145.0
P_4	44.0	50.5	40.5	135.0
P_5	50.5	55.5	50.5	156.5
P_3K_1	50.5	54.0	50.0	154.5
P_4K_1	39.5	36.5	46.0	122.0
P_5K_1	49.0	45.0	48.5	142.5
P_3K_2	47.0	45.0	45.5	137.5
P_4K_2	51.0	41.0	48.0	140.0
P_5K_2	47.5	53.0	48.5	149.0
P_3B	55.0	39.0	39.0	133.0
P_4B	38.0	53.0	48.5	139.5
P_5B	50.5	47.5	45.5	143.5
P_3K_1B	51.0	46.0	36.0	133.0
P_4K_1B	43.5	50.0	41.5	135.0
P_5K_1B	51.0	50.0	45.5	146.5
P_3K_2B	58.0	59.5	43.5	161.0
P_4K_2B	39.5	39.0	41.5	120.0
P_5K_2B	47.5	39.0	49.5	136.0

1/ See Table VI for details of treatments and statistical results.

TABLE XIX

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, THIRD CUTTING, JULY 20, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
P_3	26.0	32.0	23.0	81.0
P_4	28.0	24.0	22.0	74.0
P_5	31.5	31.0	23.5	86.0
P_3K_1	28.5	32.0	29.0	89.5
P_4K_1	30.0	25.0	27.0	82.0
P_5K_1	32.0	28.0	23.5	83.5
P_3K_2	30.0	30.0	28.5	88.5
P_4K_2	33.0	26.0	28.5	87.5
P_5K_2	32.5	28.5	24.0	85.0
P_3B	26.5	29.0	24.0	79.5
P_4B	30.0	32.5	23.0	85.5
P_5B	34.0	31.0	26.0	91.0
P_3K_1B	28.0	28.0	24.5	80.5
P_4K_1B	31.0	32.0	25.5	88.5
P_5K_1B	32.0	28.0	27.0	87.0
P_3K_2B	35.0	27.5	26.0	88.5
P_4K_2B	30.0	19.0	32.0	81.0
P_5K_2B	31.0	25.0	24.5	80.5

1/ See Table VI for details of treatments and statistical results.

TABLE XX

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS WITH THE HIGH PHOSPHATE LEVELS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, FOURTH CUTTING, OCTOBER 18, 1957

Treatment 1/	Pounds 14% moisture hay per plot			
	Rep 1	Rep 2	Rep 3	Total
P_3	13.5	26.5	18.0	58.0
P_4	15.5	22.0	22.5	60.0
P_5	22.5	21.0	21.0	64.5
P_3K_1	16.0	26.5	20.5	63.0
P_4K_1	15.5	23.0	21.0	59.5
P_5K_1	15.5	19.5	15.5	50.5
P_3K_2	24.5	24.5	25.5	74.5
P_4K_2	15.0	17.5	21.0	53.5
P_5K_2	23.0	23.0	19.0	65.0
P_3B	18.0	20.0	16.5	54.5
P_4B	23.5	23.0	19.0	65.5
P_5B	15.0	25.0	22.0	62.0
P_3K_1B	15.5	22.0	18.0	55.5
P_4K_1B	19.5	24.5	21.0	65.0
P_5K_1B	16.5	22.0	22.5	61.0
P_3K_2B	23.0	28.5	24.5	76.0
P_4K_2B	19.0	18.0	26.0	63.0
P_5K_2B	21.0	22.0	23.0	66.0

1/ See Table VI for details of treatments and statistical results.

TABLE XXI

YIELD OF ALFALFA FORAGE AS AFFECTED BY VARIOUS SOIL FERTILITY TREATMENTS, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, FIRST, SECOND, AND THIRD CUTTINGS, STILLWATER, FEBRUARY 28, APRIL 8, MAY 1, 1958

Treatment 1/	Check	Ca_4	Ca_3Mg_1	Ca_2Mg_2	Ca_1Mg_3	Mg_4	Av.
		Grams dry forage per pot first cutting 2/					
Check	4.83	4.96	4.80	4.36	4.73	4.16	4.64
P_1	4.86	5.03	5.20	4.60	5.26	5.30	5.04
K_1	5.00	4.73	4.83	5.53	4.60	5.33	5.00
P_1K_1	5.13	5.33	5.03	5.20	5.20	5.90	5.30
P_2	5.06	4.66	5.03	4.73	5.60	4.93	5.00
P_2K_1	4.83	4.66	5.33	4.70	4.83	4.46	4.81
Av.	4.95	4.89	5.03	4.86	5.03	5.01	4.93
Sm = .167		Treatment F = 1.51 n.s.			C. V. = 10.20%		
		Grams dry forage per pot second cutting 2/					
Check	3.70	4.56	3.50	4.33	5.06	4.96	4.35
P_1	5.00	3.90	4.43	4.10	4.73	5.26	4.57
K_1	4.53	4.93	4.10	4.80	4.33	5.13	4.63
P_1K_1	4.16	4.40	4.43	5.30	5.10	4.80	4.70
P_2	4.40	4.36	4.23	5.20	4.96	4.83	4.66
P_2K_1	3.90	3.96	4.00	4.76	4.56	4.53	4.28
Av.	4.28	4.35	4.12	4.75	4.79	4.92	4.53
Sm = .176		Treatment F = 1.97**			C. V. = 11.69%		
		Grams dry forage per pot third cutting 2/					
Check	1.73	2.36	2.00	2.76	2.46	2.76	2.35
P_1	2.80	2.40	2.66	2.23	2.83	2.93	2.64
K_1	2.50	2.16	2.26	1.86	2.28	3.06	2.35
P_1K_1	2.33	2.40	2.66	2.90	2.86	2.70	2.64
P_2	2.13	2.43	2.13	3.10	2.30	3.30	2.57
P_2K_1	2.13	2.33	2.46	2.90	3.13	3.13	2.68
Av.	2.27	2.35	2.36	2.63	2.64	2.98	2.53
Sm = .179		Treatment F = 1.52 n.s.			C. V. = 21.30%		

1/ See Table VIII for details of treatments.
2/ Yield figures represent the mean of three replicate pots.
n.s. = Not significant at 5% level.
** = Significant at 1% level.

VITA

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