EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS ON ALFALFA YIELD AND COMPOSITION WITH EMPHASIS ON CALCIUM AND MAGNESIUM RATIOS

By

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I INTRODUCTION

Alfalfa is one of the most palatable and nutritious crops grown for forage in the United States (15). Its importance in Oklahoma is reflected in its increased acreage within the state. Establishment and maintenance of this perennial legume is dependent on successful management and soil fertility practices. The high plant nutrient requirements of alfalfa have been recognized (2).

A comprehensive research study concerning the soil fertility requirements for alfalfa grown on representative soil types within the state has been initiated at the Oklahoma Agricultural Experiment Station. The objective of field and greenhouse studies was to determine the response of alfalfa to various soil fertility treatments. The treatments in the field experiment included three rates of phosphorus and potassium, two rates of boron and a trace element study that was concerned with boron, magnesium, sulfur and manganese. The treatments in the greenhouse were concerned with calcium and magnesium ratios applied with and without phosphorus and potassium.

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[1]Figures in parenthesis refer to literature cited.

II REVIEW OF LITERATURE

Alfalfa thrives best on medium textured soils that are deep, permeable, and well drained, but it is also tolerant to a wide range of soil conditions (15). However, different responses to management and fertility practices are frequently encountered on various soils in different climatic regions.

Calcium and Magnesium

This crop has a high requirement for calcium and magnesium and apparently requires a pH of 6.0 for best growth response (2). Hull (21) in Wisconsin, concluded that if lime and an adequate supply of phosphate are present within the first five feet of the surface, the calcium and phosphorus needs of alfalfa may be satisfied even though the surface soil is deficient in calcium.

Bower and Turk (6) found that naturally occurring alkali soils, high in exchangeable sodium, may not furnish an adequate supply of calcium even though calcium carbonate is present in large amounts.

Schmehl, et al. (42) studied the influence of soil acidity on the absorption of calcium by alfalfa using radiocalcium. They found that the rate of absorption of calcium by alfalfa was markedly reduced in the presence of aluminum,

manganese, and hydrogen ions in a nutrient media. They concluded that the low calcium content in plants grown on acid soils may result from either an antagonistic effect or restricted root growth in an acid subsoil, rather than to a low supply of calcium in the soil.

Overliming of alfalfa is usually accompanied by reduced yields. According to Turk and Lynd (51), 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 (25) were able to prevent overliming injury by application of manganese sulfate. They found a marked decrease in exchangeable manganese in the soil with increasing rates of lime, but the quantity of exchangeable potassium and adsorbed phosphorus was not appreciably affected.

Liming of alfalfa to optimum pH levels is closely related to yield. Moser (29) showed that calcium supplied at low pH values was a more important growth factor than pH. His results indicated that calcium supplied in increasing increments gradually increased in the plant, reaching the maximum where 10 m.e. of calcium were applied at the pH of 6.0 to 6.5. Albrecht and Schroeder (1) studied the influence of soil acidity on the activity of the calcium present. They reported that a greater activity of the calcium in the soil occurred when a significant amount of hydrogen was present than when a soil was of neutral reaction. Truog (49)

found large amounts of calcium in combination with organic acids which are thought to be by-products of vital life processes.

Scanlan (41) working with inoculation of soybeans, found that increased nodulation was not caused by altering the pH but was caused by supplying calcium to the infecting organism.

Elgabaly (11) studied the specific effects of adsorbed ions on plant growth. His results with barley indicated that adsorbed sodium had a higher activity than that of calcium or magnesium in a saturated sodium system. In the Ca:Mg system, plants absorbed magnesium at all degrees of magnesium saturation. Calcium depletion of the system occurred at 82 percent calcium saturation. The maximum barley yield was obtained from a 70:30 Ca:Mg system. Hunter (22) found no relationship between the Ca:Mg ratio and yield. Variations in the Ca:Mg ratio ranged from 1:4 to 32:1, values both higher and lower than those normally found in soils.

Woodhouse (54) in North Carolina, concluded that the time and method of application were more important than the rate of application of lime. Best results were obtained by mixing the lime in the plow layer before planting. His data indicated that more benefit was derived from pH change than the supply of calcium and magnesium to the plants. Nelson and MacGregor (36) were able to show that spring and fall applied fertilizers were equally effective on yield, composition and longevity of alfalfa.

Fine textured soils have been found to contain more magnesium than sandy soils. According to Millar (28), the chlorophyll molecule contains 2.7 percent magnesium, but data indicates that considerably more magnesium is necessary to produce the maximum rate of photosynthesis.

Camp (8) studying citrus fertilization in Florida, found that dolomite alone was not adequate as a magnesium source and that some soluble source of magnesium had to be used to supplement it. He also found that as the pH of soils in commercial citrus groves was raised, dolomite became progressively less valuable as a source of magnesium.

Calcium and magnesium requirements seem to influence each other. McMurtrey (35), working with tobacco, found that the amounts of calcium and magnesium necessary for normal growth indicated that calcium must be absorbed in larger quantities than magnesium.

Knoblauch and Odland (24), in studies concerning magnesium deficiencies, found that continued application of potassium on acid soils at high rates caused a severe magnesium deficiency. It was thought that the potassium ion influenced the absorption of magnesium through their related position on the colloidal clay complex.

One of the functions ascribed to magnesium is that of a carrier of the phosphorus used by the plant. Truog et al. (50) found that a high phosphorus content of pea seed was correlated with a high magnesium content and a high level of available magnesium. This information supports the

hypothesis that magnesium functions as a phosphate carrier. The role of magnesium as an activator of many enzyme systems is a possible explanation of the magnesium-phosphorus relationship in plants (53).

Phosphorus

Alfalfa uses relatively large amounts of phosphorus. Only a small part of the phosphorus fertilizers added to the soil as available phosphorus is used by the plants (30). Seay and Weeks (44) indicated that the best time for application of phosphate fertilizers was during the fall. They also found that phosphorus was taken up by alfalfa during the dormant season.

MacLean and Cook (34) studied the effect of soil reaction on phosphorus availability and found that liming to slightly above the neutral point increased the amount of available soil phosphorus. Hausenbuiller et al. (19) compared phosphate fertilizers on Washington soils and found that fertilizer phosphorus was neither leached from the soil nor converted 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. Hunter (22) concluded that the level of available phosphate in the soil was the most important factor affecting the phosphorus content on alfalfa.

Potassium

Seay et al. (45) working with Wisconsin soils, found a linear relationship to exist 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.

Jenny and Shade (23) working with pure clay minerals found that lime liberated adsorbed potassium in large quantities. Application of lime increased the microbiological activity of the soil causing a reduction in the available potassium below that of an untreated soil. Bear (3) found that when large amounts of potassium were available to plants, the uptake of calcium and magnesium was greatly reduced.

Peech and Bradfield (38) indicated that potassium uptake was not affected appreciably by calcium, whereas potassium suppressed the uptake of both calcium and magnesium. Murphy (32) found that soils containing less than 60 p.p.m. of replaceable potassium generally responded to potassium fertilization if other factors were favorable for plant growth. Hood and Brady (20) found that water soluble potassium gave a better measure of immediately available potassium than exchangeable potassium when rapidly growing plants were used and the growing season was short.

Stand maintenance of alfalfa was found to be closely related to both potassium fertilization and potassium content of the plant (48). Tests indicated that the stand was

decreased 36 percent on the check as compared to a 400 pound per acre rate of potassium. The percentage potassium in the alfalfa plant necessary for survival was .9 to 1.1. Bear and Toth (4) found that alfalfa plants had the tendency to take up excess potassium at the expense of magnesium when excessive applications of potassium were made.

Trace Elements

In many instances the trace elements are the first limiting factor in plant growth. 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 (47) found that the total boron content of alfalfa varied directly with the water soluble boron content of the soil. He observed boron deficiency symptoms on alfalfa in which the total boron content was less than 20 p.p.m. when the water soluble boron content of the soil was less than .5 p.p.m. Dible and Berger (9) thought that an analysis of the apical area of the alfalfa plant, rather than the total shoot, would serve as a better criterion of the boron status since boron is immobile in the plant. They reported that the level indicating a boron deficiency was approximately 9 p.p.m. Brown and King (7) decreased boron deficiency symptoms, increased height by 15 percent and yields by 16 percent. Boron content of the leaves was increased by 21 to 62 percent with application of 20 pounds of borax per acre

as compared with the alfalfa that was not fertilized with boron.

Boron fixation is known to increase rapidly with an increase in pH. Olson and Berger (37) found that the amount of calcium salts added to the soil did not influence boron fixation unless the pH was increased above 7. Their evidence indicates that most of the boron is fixed by the clay fraction of the soil. Muhr (31) studied available boron with soybean yield. He obtained yield increases with applications of borax until a conc. of 30 p.p.m. of boron was reached in the plant. The toxic range was reached when the plant tissue contained 50 to 60 p.p.m. of boron.

Manganese deficiency commonly occurs on soils of high pH and of high organic matter content (51). Lynd and Turk (25) found that with increasing rates of lime there was a marked decrease in exchangeable manganese. Vavra and Frederick (52) found that the oxidation of elemental sulfur or sodium thiosulfate applied to the soil resulted in release of soluble manganese accompanied by a lowering of pH. They also found that addition of lime caused a decrease in the amount of soluble manganese released, although the amount of sulfate released was not changed significantly.

Garey and Barber (14) studied manganese deficiency on soils in Indiana. Their results indicated that the yield of soybeans was proportional to the change in pH after an application of elemental sulfur. They found that applications of elemental sulfur and sodium thiosulfate caused an

increase in the sulfate ion concentration of the plant. A pH change also occurred in the soil sufficient to correct the manganese deficiency and to promote increased yields. Haddock and Vandecavey (16), using two western Washington soils, received none to slight yield response from manganese fertilization. Sulfur appeared to be the first limiting factor on these soils. In order to determine the requirements of these soils for potassium and phosphorus, sulfur had to be applied as a blanket type treatment. 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 an acre annually in most areas.

III MATERIALS AND METHODS

Soils Used in the Field Experiment

A field experiment on Port loam was located on the Thomas farm about 2½ miles east of Stillwater, in Payne County, Oklahoma near State Highway 51 in the NW¼NW¼ sec. 20, Twp. 19N; R. 1E.

This soil was formed from material of alluvial origin and is located on an occasionally inundated flood plain. Port loam soil has a brown topsoil about 16 inches in depth; which has a medium granular structure and friable consistence. It is underlain by calcareous, reddish-brown material. A detailed description of this soil series may be found in the Manual of Soil Series of Oklahoma (26). This field has been in continuous corn since 1948 and had not received any lime during that period. This may account for the low pH shown in Table 1.

The plots on Norge fine sandy loam were located on the Paradise farm, about 9 miles south and 6 miles west of Stillwater, in Payne County, Oklahoma in the SE¼SE¼ sec. 34, Twp. 18N; R.1E.

This soil was formed from parent material of sandstone. 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

TABLE I. SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS USED IN THE FIELD EXPERIMENT.

	Thomas farm Port loam	Blackwell Lake Port silty clay loam	Paradise Norge fine sandy loam
Texture:			
Percent sand	43.0	24.0	72.0
Percent silt	38.0	55.0	20.0
Percent clay	19.0	21.0	8.0
Reaction (pH)	5.0	5.8	7.1
Percent organic matter	1.42	2.80	1.00
Percent nitrogen	.077	.102	.019
Available phosphorus (pounds per acre)	21.76	15.40	10.90
Exchangeable potassium (M.E./100 gms.)	.24	.31	.19
Cation exchange capacity (M.E./100 gms.)	7.96	11.89	4.18

this soil series may be obtained from the Manual of Soil Series of Oklahoma (26).

The plots on the Port silty clay loam were located on the Blackwell Lake Station about 14 miles west and 2 miles north of Stillwater, Oklahoma near Highway 51 in the NW¼NW¼ sec. 11, Twp. 19N; R. 1W.

This soil was formed from material of alluvial origin and is located on an occasionally inundated flood plain. This Port silty clay loam soil has a reddish-brown topsoil about 30 inches in depth; it has weak medium sub-angular blocky structure with firm consistence over calcareous reddish-brown material. A buried soil horizon occurs at 18-30 inches depending on the sampled sites. A detailed description of this soil series is available (13).

Field Experiments

Experiments were started on an established stand of alfalfa in February of 1955 at the Thomas farm and in 1956 at the Blackwell Lake and Paradise farms. These treatments included annual applications of the following treatments:

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).

These plots were laid out in a complete factorial split-plot arrangement in a randomized block having all possible

combinations of the above treatments with three replications.

Trace element studies were conducted at adjacent areas on these three stations. The treatments were as follows:

B = 40 pounds borax per acre (11.3% boron).

Mg = 480 pounds per acre ($MgSO_4$).

Mn = 50 pounds per acre ($MnSO_4$).

S = 50 pounds per acre as Flowers of Sulfur.

BMgMnS = A combination of the above elements and rates.

K_2P_2 = 200 pounds of K_2O and 80 pounds of P_2O_5 supplied as a blanket treatment on all plots.

The trace element treatments were laid out in a completely randomized block design and replicated three times. Results of some chemical and physical properties of these soils are presented in Table I.

Chemical determinations were made on the plant material which included analyses for total nitrogen, phosphorus, and potassium. Nitrogen was determined by the Kjeldahl method (40). Samples were prepared for analyses on phosphorus and potassium by using a modification of the nitric-perchloric wet digestion method as designed by Piper (40). Phosphorus was determined by reducing phosphomolybdate with hydrazine sulfate. Potassium was determined by use of the Perkin-Elmer Flame Photometer.

Soils Used in the Greenhouse Experiment

Port loam and Waynesboro loam soils were selected for this experiment. Some chemical and physical properties of these soils are listed in Table II. The Port loam soil was selected because it is representative of the deep, well drained, permeable, medium textured soils commonly used for alfalfa production in Oklahoma. The Waynesboro loam was selected from an area in Southeastern Oklahoma where previous investigation has shown a response to boron fertilization (33).

Port loam. A bulk sample of Port loam soil was taken from the plow layer (0-6") from the Thomas farm about 2½ miles east of Stillwater, Payne County, Oklahoma. The approximate location of the sampling site was 500 yards south and 40 yards east of the northwest corner of the farm which is located in the NW¼NE½ sec. 20, Twp. 19N; R. 3E. A detailed description of this soil series may be found in the Manual of Soil Series of Oklahoma (26).

Waynesboro loam. A bulk sample from the plow layer, (0-6"), was taken from the Southeastern Oklahoma Soil Improvement Station which is located about 2½ miles north of Heavener, Leflore County, Oklahoma. The sampling location was about 300 yards south and 600 yards west of the Community Building located in the NW¼NW¼ sec. 7, Twp. 5N; R. 26E. A detailed description of this soil may be found in the Report of Soil Survey (12).

TABLE II. SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS USED IN THE GREENHOUSE EXPERIMENT.

	Port loam	Waynesboro loam
Texture:		
Percent sand	43.0	41.75
Percent silt	38.0	40.50
Percent clay	19.0	17.75
Reaction (pH)	5.0	6.5
Percent organic matter	1.42	1.37
Percent nitrogen	.079	.069
Available phosphorus (pounds per acre)	21.76	16.96
Exchangeable potassium (M.E./100 gms.)	.24	.18
Exchangeable Calcium (M.E./100 gms.)	4.78	2.10
Exchangeable Magnesium (M.E./100 gms.)	2.82	.35
Cation exchange capacity (M.E./100 gms.)	7.96	7.56

> "In general this soil has a brown loam surface five to eight inches in depth over a reddish-yellow clay loam subsoil which is mottled with red in the lower part and becomes streaked with gray at about four feet. The material is clay loam and contains occasional pebbles to at least eight feet, the greatest depth sampled. In some profiles thick pebble layers are found at depths as shallow as 24 inches." 1/

Results of some physical and chemical properties of these soils are presented in Table II. Mechanical analyses were made by the hydrometer method essentially as presented by Bouyoucos (5). Available phosphorus was determined by leaching with 0.1 normal acetic acid as proposed by Harper (17). Exchange capacity and exchangeable potassium were determined by the procedures presented by A.O.A.C. (27), using neutral normal ammonium acetate as the extracting agent. Total nitrogen was determined by a modification of the Kjeldahl method (40). The percentage organic matter was determined by the procedure outlined by Schollenberger (43). Soil reaction was determined by the method presented by Peach and English (39), using the Beckman glass-electrode potentiometer. Samples were prepared for exchangeable calcium determinations by a wet digestion method, and exchangeable magnesium was measured using the 8-hydroxy quinoline dye technique (18).

1/ Personal communication with Galloway.

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 and chemical composition of alfalfa grown on two soil types.

The soils were collected from the field, screened through a $\frac{1}{4}$ inch mesh screen and air-dried. The containers used for this experiment were two-gallon, glazed, earthenware pots. Eight kilograms of soil were weighed into a sufficient number of pots to enable all treatments to be made in triplicate. Each of the twenty treatments were replicated three times on each soil, making a total of 120 pots. The treatments were designated as follows:

Check	K_1	P_1	P_1K_1
Ca_4	Ca_4K_1	Ca_4P_1	$Ca_4P_1K_1$
Mg_4	Mg_4K_1	Mg_4P_1	$Mg_4P_1K_1$
Ca_3Mg_1	$Ca_3Mg_1K_1$	$Ca_3Mg_1P_1$	$Ca_3Mg_1P_1K_1$
Ca_2Mg_2	$Ca_2Mg_2K_1$	$Ca_2Mg_2P_1$	$Ca_2Mg_2P_1K_1$

Symbols:

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.

K_1 = 100 pounds K_2O per acre as KCl (C.P.).

P_1 = 100 pounds P_2O_5 per acre as $Ca_2(HPO_4)_2$ (C.P.).

Phosphorus and potassium were supplied in solution. Other treatments were mixed thoroughly with the soil. Moisture equivalent values were determined for each soil. On the basis of this determination, each soil was watered to field capacity before planting. The soils were planted to certified Buffalo alfalfa, Medicago sativa, October 20, 1956. The seeds were soaked in an inoculum, Rhizobium species for 48 hours 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 cutting was harvested February 6, 1957. The second cutting was harvested April 1, 1957. The plant material was dried in the oven at 65° C. and weighed; then ground for later chemical analyses.

Statistical Analysis

Alfalfa hay yields and chemical composition were subjected to statistical analyses to aid in interpreting the data.

Analyses of variance for significant differences, coefficients of variation and standard errors were determined as proposed by Snedecor (46). When a significant value was obtained in the analysis of variance, a Multiple Range Test was made on the data using the standard error of the mean according to Duncan (10).

IV RESULTS AND DISCUSSIONS

The purpose of these greenhouse and field experiments was to determine the response of alfalfa to various soil fertility treatments on several soil types. Results were obtained from three field experiments and one greenhouse experiment.

Field Experiments

Port loam: Two cuttings of alfalfa hay were harvested in 1956 and yields from this experiment are summarized in Table III. The actual plot yields with detailed analyses of variance are shown in the Appendix, Tables XIII, XIV and XV.

The lowest total yield, 1098 pounds per acre, was obtained from the P_1B treatment. The highest total yield, 1724 pounds per acre was obtained from the P_2K_2B treatment. The analysis of variance indicated significance at the 5% level of probability to potassium fertilization at the three rates used. This relationship of potassium fertilization indicated a significant linear response. There were no significant interactions among the various fertility treatments including boron.

The total contents of nitrogen, phosphorus, and potassium were determined on the alfalfa hay produced in the second cutting of this experiment. Results of the nitrogen phosphorus and potassium determinations are summarized in

TABLE III. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, STILLWATER, 1956.

Treatments 2/	Pounds of hay per acre at cutting date. 1/ 6/12	7/21	Av. Total Yield
Check	1212	277	1489
P_1	1135	222	1357
P_2	1008	238	1246
K_1	1246	281	1527
P_1K_1	1204	281	1485
P_2K_1	1246	311	1557
K_2	1289	277	1566
P_1K_2	1157	225	1382
P_2K_2	1212	387	1599
B	1064	272	1336
P_1B	881	217	1098
P_2B	1115	264	1379
K_1B	1051	277	1328
P_1K_1B	1242	306	1548
P_2K_1B	1319	353	1672
K_2B	1072	187	1259
P_1K_2B	1221	238	1459
P_2K_2B	1353	371	1724

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%)

Multiple Range, 5% Level, S_m = 2.988. Trt. F(K-level)=4.62* C.V.=15.21%.

P_1B	P_2	K_2B	K_1B	B	P_1	P_2B	P_1K_2	P_1K_2B	P_1K_1	Ck.	K_1	P_1K_1B	P_2K_1	K_2	P_2K_2	P_2K_1B	P_2K_2B
1098	1246	1259	1328	1336	1357	1379	1382	1459	1485	1489	1527	1548	1557	1566	1599	1672	1724

Any two means underscored by the same line are not significantly different.

Table IV.

The forage containing the lowest nitrogen content, 2.88 percent, was produced on plots receiving P_1K_1 treatment. The forage containing the highest percentage nitrogen, 3.43 percent, was produced in the check plots receiving no treatment. The plants produced in plots that received the B treatment contained the lowest percentage phosphorus, .196 percent, and the plants produced in plots that received the P_2K_1B treatment contained the highest percentage phosphorus, .247 percent. Percentage potassium content, 1.16 percent, was lowest on those plants receiving the P_2 treatment and was highest, 1.54 percent, in the alfalfa receiving the K_2B treatment.

Port silty clay loam: In 1956, two alfalfa hay cuttings were taken from this experiment and yields are summarized in Table V. The actual plot yields with detailed analyses of variance are shown in the Appendix, Tables XVI, XVII and XVIII.

TABLE IV. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, STILLWATER, SECOND CUTTING, JULY 21, 1956.

Treatments [2]	Percentage of Nitrogen [1]		
	0	K_1	K_2
Check	3.43	3.35	3.09
P_1	3.28	2.88	3.31
P_2	2.98	3.01	3.26
B	3.18	3.23	3.41
P_1B	3.37	2.93	3.26
P_2B	3.26	3.33	3.06
Average	3.25	3.12	3.24

Treatments	Percentage of Phosphorus [1]		
	0	K_1	K_2
Check	.227	.208	.207
P_1	.214	.220	.226
P_2	.223	.241	.238
B	.196	.209	.211
P_1B	.216	.220	.241
P_2B	.232	.247	.228
Average	.218	.224	.225

Treatments	Percentage of Potassium [1]		
	0	K_1	K_2
Check	1.18	1.35	1.42
P_1	1.20	1.37	1.48
P_2	1.16	1.20	1.36
B	1.26	1.40	1.54
P_1B	1.28	1.42	1.46
P_2B	1.33	1.38	1.49
Average	1.24	1.35	1.46

1/ Each figure represents the mean of two analyses obtained by combining forage samples from three replicate plots receiving the same fertility treatments.

2/ See Table III for details of treatments.

TABLE V. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, BLACKWELL LAKE STATION, PORT SILTY CLAY LOAM, STILLWATER, 1956.

Treatment 2/	Pounds of hay per acre at cutting date. 1/ 6/11	7/18	Av. Total Yield
Check	1051	651	1702
P_1	1149	753	1902
P_2	1212	557	1769
K_1	1136	787	1923
P_1K_1	1034	778	1812
P_2K_1	1306	830	2136
K_2	1072	889	1961
P_1K_2	1183	885	2068
P_2K_2	1297	872	2169
B	978	447	1425
P_1B	1136	821	1957
P_2B	1127	604	1731
K_1B	902	540	1442
P_1K_1B	1093	893	1986
P_2K_1B	1136	766	1902
K_2B	949	676	1625
P_1K_2B	1127	915	2042
P_2K_2B	1161	876	2037

1/ Yield figures are the mean of three replications.
2/ See Table III for details of treatments.

Treatment F (P-level) = 4.19* Coefficient of Variation = 18.79%.

Multiple Range Test, 5% Level, S_m = 4.632.

B	K_1B	K_2B	Ck.	P_2B	P_2	P_1K_1	P_2K_1B	P_1	K_1	P_1B	K_2	P_1K_1B	P_2K_2B	P_1K_1B	P_1K_2	P_2K_1	P_2K_2
1425	1442	1625	1702	1731	1769	1812	1902	1902	1923	1957	1961	1986	2037	2042	2068	2136	2169

Any two means underscored by the same line are not significantly different.

Lowest total yield, 1425 pounds per acre, was obtained from the B treatment. Highest total yield, 2169 pounds per acre, was obtained from the P_2K_2 treatment. Analysis of variance indicated significant response at the 5% level to phosphorus fertilization at the three rates used. The relationship of phosphorus fertilization indicated a linear response. There were no significant interactions between treatments.

Chemical determinations were made on the alfalfa hay for percentage nitrogen, phosphorus and potassium, and results of the first cutting are summarized in Table VI.

Plants receiving the B treatment contained the lowest nitrogen content, 1.48 percent, and plants receiving the K_2 treatment contained the highest nitrogen content, 3.25 percent. Phosphorus content, .230 percent, was lowest on those plants receiving the B treatment and phosphorus content, .298 percent, was highest on those plants receiving the no fertilizer treatment (check). Lowest potassium content, .91 percent, was contained in plants produced on plots that received P_2K_2 treatment and highest potassium content, 1.63 percent, was contained in plants produced on plots that received no fertilizer treatment (check).

Results from chemical determinations for nitrogen, phosphorus and potassium content of alfalfa hay of the second cutting are summarized in Table VII.

TABLE VI. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF ALFALFA HAY, FIELD EXPERIMENT, BLACKWELL LAKE STATION, PORT SILTY CLAY LOAM, STILLWATER, FIRST CUTTING, JUNE 11, 1956. 1/

Treatments 2/	Percentage of Nitrogen		
	0	P_1	P_2
Check	2.84	2.83	2.98
K_1	2.44	2.79	2.60
K_2	2.79	3.26	2.41
B	1.48	2.56	2.04
K_1B	2.67	2.46	2.79
K_2B	2.88	2.72	2.62
Average	2.52	2.77	2.57

Treatments	Percentage of Phosphorus		
	0	P_1	P_2
Check	.298	.254	.258
K_1	.258	.274	.265
K_2	.263	.276	.267
B	.230	.265	.286
K_1B	.259	.262	.259
K_2B	.273	.266	.267
Average	.264	.266	.267

Treatments	Percentage of Potassium		
	0	P_1	P_2
Check	1.63	1.43	1.09
K_1	1.48	1.42	1.46
K_2	1.33	1.50	0.91
B	1.01	1.29	1.32
K_1B	1.27	1.08	1.21
K_2B	1.27	1.19	1.10
Average	1.33	1.32	1.18

1/ Each figure represents the mean of duplicate analyses on forage samples obtained by combining the plant materials from three replicate plots receiving the same treatments.

2/ See Table III for details of treatments.

Plants receiving the P_2K_1 treatment contained the lowest nitrogen content, 2.25 percent, and plants receiving P_2B treatment contained the highest nitrogen content, 3.21 percent.

The lowest phosphorus content, .199 percent, was obtained from those plants that received the P_1 treatment. The highest phosphorus content, .241 percent, was obtained from those plants that received P_1K_1B treatment.

The lowest potassium content, 1.28 percent, was obtained from plants that received the P_2B treatment and the highest potassium content, 1.84 percent, was contained in plants that received the P_2 treatment.

Norge fine sandy loam: Two alfalfa hay cuttings were taken from this experiment in 1956 and yields are summarized in Table VIII. The actual plot yields with a detailed analyses of variance are shown in the Appendix, Tables XIX, XX and XXI.

Lowest total yield, 985 pounds per acre, was obtained from the check (no fertilizer) plots. Highest total yield, 1232 pounds per acre was obtained from the P_1K_1B treatment. There was a significant influence on yield from application of boron as a soil fertility treatment.

TABLE VII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF ALFALFA HAY, FIELD EXPERIMENT, BLACKWELL LAKE STATION, PORT SILTY CLAY LOAM, STILLWATER, SECOND CUTTING, JULY 18, 1956.1/

	Percentage of Nitrogen		
Treatments 2/	0	P_1	P_2
Check	2.88	2.58	2.78
K_1	2.44	2.50	2.25
K_2	2.67	2.87	3.00
B	2.78	2.79	3.21
K_1B	2.66	3.13	2.99
K_2B	3.02	3.09	3.13
Average	2.74	2.83	2.89

	Percentage of Phosphorus		
Treatments	0	P_1	P_2
Check	.208	.199	.208
K_1	.208	.203	.217
K_2	.208	.218	.220
B	.202	.214	.218
K_1B	.220	.241	.224
K_2B	.220	.232	.212
Average	.211	.218	.217

	Percentage of Potassium		
Treatments	0	P_1	P_2
Check	1.52	1.56	1.84
K_1	1.52	1.52	1.46
K_2	1.58	1.58	1.52
B	1.44	1.44	1.28
K_1B	1.56	1.72	1.52
K_2B	1.58	1.56	1.52
Average	1.53	1.56	1.52

1/ Each figure represents the analyses on forage samples obtained by combining the plant material from three replicate plots receiving the same fertility treatments.
2/ See Table III for details of treatments.

Chemical determinations were made on the alfalfa hay for percentage nitrogen, phosphorus and potassium content and the results for the first cutting are summarized in Table IX.

Percentage nitrogen of the first cutting is lowest, 3.19 percent, on those plants that received the P_1K_1B treatment. The highest content of nitrogen, 3.74 percent, was produced on those plants that received the P_2K_2B treatment.

Plants containing the lowest phosphorus content, .231 percent, were obtained from plots that received the P_1 treatment, and plants containing the highest phosphorus content, .263 percent, were obtained from plots that received the P_2K_2B and P_2K_1B treatments.

Lowest potassium content, 1.18 percent, was obtained from plants that received the P_2 treatment, and K_2B treatment produced plants that contained the highest potassium content, 1.93 percent.

Chemical determinations were made on the second cutting for nitrogen, phosphorus and potassium and the results are summarized in Table X.

Lowest nitrogen content, 3.06 percent, was obtained from plants that received the P_2K_2B treatment, and the highest nitrogen content, 3.42 percent, was obtained from plants that received the K_2B treatment.

TABLE VIII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY IN THE FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, STILLWATER, 1956.

Treatments 2/	Pounds of hay per acre at cutting date. 1/ 6/13	7/22	Av. Total Yield
Check	753	232	985
P_1	766	281	1047
P_2	778	253	1031
K_1	864	317	1181
P_1K_1	808	241	1049
P_2K_1	778	246	1024
K_2	838	280	1118
P_1K_2	859	228	1087
P_2K_2	787	222	1009
B	821	277	1098
P_1B	893	307	1200
P_2B	872	325	1197
K_1B	893	301	1194
P_1K_1B	881	351	1232
P_2K_1B	830	305	1135
K_2B	885	270	1155
P_1K_2B	915	277	1192
P_2K_2B	859	299	1158

1/ Yield figures are the mean of three replications.
2/ See Table III for details of treatments.

Treatment F (B-level) = 7.54** Coefficient of Variation = 13.68

TABLE IX. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, STILLWATER, FIRST CUTTING, JUNE 13, 1956.

Percentage of Nitrogen [1]

Treatments [2]	0	P_1	P_2	K_1	P_1K_1	P_2K_1	K_2	P_1K_2	P_2K_2	Av.
No Boron	3.56	3.42	3.70	3.53	3.28	3.50	3.26	3.43	3.57	3.47
Boron	3.61	3.72	3.36	3.64	3.19	3.44	3.50	3.67	3.74	3.54

Percentage of Phosphorus [1]

Treatments	0	P_1	P_2	K_1	P_1K_1	P_2K_1	K_2	P_1K_2	P_2K_2	Av.
No Boron	.247	.231	.249	.245	.260	.256	.232	.248	.259	.247
Boron	.239	.259	.254	.231	.258	.263	.232	.258	.263	.251

Percentage of Potassium [1]

Treatments	0	P_1	P_2	K_1	P_1K_1	P_2K_1	K_2	P_1K_2	P_2K_2	Av.
No Boron	1.20	1.29	1.18	1.81	1.59	1.91	1.84	1.59	1.88	1.59
Boron	1.70	1.72	1.71	1.80	1.80	1.28	1.93	1.86	1.83	1.73

[1] Each figure represents the analyses on forage samples obtained by combining the plant materials from three replicate plots receiving the same fertility treatments.

[2] See Table III for details of treatments.

Lowest phosphorus content, .181 percent, was obtained from the check plots that received no fertilizer (check) treatment. Highest phosphorus content, .215 percent, was obtained from plots that received the P_2K_2B treatment.

Lowest potassium content, 1.58 percent, was obtained on plants that received the P_2 treatment. Alfalfa hay from the P_2K_2B treatment contained the highest potassium content, 2.18 percent.

Two alfalfa hay cuttings were taken from each of the trace element experiments at the three locations in 1956. These studies were concerned with trace element fertility treatments and yields are summarized in Appendix, Table XXII. There was no consistent yield differences apparent as a function of the various trace element treatments.

The drouth conditions that existed throughout the growing season of 1956 undoubtedly had a large influence on the response obtained from the various kinds and rates of fertilizer applied in these experiments.

TABLE X. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, STILLWATER, SECOND CUTTING, JULY 21, 1956.

Percentage of Nitrogen [1]

Treatments [2]	0	P_1	P_2	K_1	P_1K_1	P_2K_1	K_2	P_1K_2	P_2K_2	Av.
Check	3.07	3.15	3.23	3.27	3.41	3.23	3.23	3.19	3.17	3.22
Boron	3.24	3.13	3.31	3.38	3.21	3.36	3.42	3.13	3.06	3.25

Percentage of Phosphorus [1]

Treatments	0	P_1	P_2	K_1	P_1K_1	P_2K_1	K_2	P_1K_2	P_2K_2	Av.
Check	.181	.190	.199	.199	.190	.196	.184	.199	.197	.193
Boron	.190	.199	.209	.196	.201	.199	.194	.197	.215	.200

Percentage of Potassium [1]

Treatments	0	P_1	P_2	K_1	P_1K_1	P_2K_1	K_2	P_1K_2	P_2K_2	Av.
Check	1.76	1.92	1.58	1.94	1.80	1.94	1.94	1.92	2.06	1.87
Boron	1.88	1.94	1.92	2.10	1.94	1.98	2.10	1.94	2.18	2.00

[1] Each figure represents the analyses on forage samples obtained by combining the plant materials from three replicate plots receiving the same fertility treatments.

[2] See Table III for details of treatments.

Greenhouse Experiment

Port loam: Two alfalfa hay cuttings were taken from this experiment in 1957 and yields are summarized in Table XI. The actual pot yields with detailed analyses of variance are shown in the Appendix, Tables XXIII, XXIV and XXV.

The plants grown in pots that received the Mg_4 treatment produced the lowest total yield, 2.52 grams. The highest total yield, 7.33 grams, was obtained from those plants grown in pots that received the Ca_4 treatment. Analyses of variance indicated significance among calcium and magnesium rates (main treatments) at the 1% level and significance was indicated among phosphorus and potassium rates (sub-treatments) at the 5% level. Interactions between the phosphorus and potassium treatments were significant at the 1% level. There was no significant interaction between the main treatments and the sub-treatments.

Waynesboro loam: Two alfalfa hay cuttings were taken from this experiment in 1957 and yields are summarized in Table XII. The actual pot yields with detailed analyses of variance are shown in the Appendix, Tables XXVI, XXVII and XXVIII.

Lowest total yield, 0.20 grams, essentially a crop failure, was obtained from the plants grown in pots that received the Mg_4 treatment. The highest total yield, 7.19

TABLE XI. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, PORT LOAM, STILLWATER, 1957.

Treatments 2/	Grams of oven dry forage per pot.1/ 2/6	4/1	Av. Total Yield
Check	1.70	2.83	4.53
Ca_4	1.73	5.60	7.33
Mg_4	.46	2.06	2.52
Ca_3Mg_1	1.36	5.03	7.39
Ca_2Mg_2	1.36	4.56	5.92
K_1	1.46	3.90	5.36
Ca_4K_1	1.70	5.56	7.26
Mg_4K_1	1.16	4.06	5.22
$Ca_3Mg_1K_1$	1.46	4.90	6.36
$Ca_2Mg_2K_1$	1.46	5.03	6.49
P_1	1.46	3.63	5.09
Ca_4P_1	1.70	5.36	7.06
Mg_4P_1	.63	3.93	4.56
$Ca_3Mg_1P_1$	1.20	5.13	6.33
$Ca_2Mg_2P_1$	1.43	4.56	5.99
P_1K_1	1.46	3.63	5.09
$Ca_4P_1K_1$	1.46	4.96	6.42
$Mg_4P_1K_1$	.96	3.36	4.32
$Ca_3Mg_1P_1K_1$	1.03	4.86	5.89
$Ca_2Mg_2P_1K_1$	1.03	5.16	6.19

1/ Yield figures are the mean of three replications.

2/ Treatment symbols are:

Check	No fertilizer
Ca_4	10 tons of $CaCO_3$ per acre (tech. grade).
Mg_4	8.4 tons $MgCO_3$ per acre (C. P.).
Ca_3Mg_1	7.5 tons $CaCO_3$ and 2.1 ton $MgCO_3$ per acre as above.
Ca_2Mg_2	5.0 tons $CaCO_3$ and 4.2 ton $MgCO_3$ per acre as above.
K_1	100 pounds K_2O per acre as KCl (C. P.).
P_1	100 pounds P_2O_5 per acre as $Ca_2(HPO_4)2$ (C. P.).

TABLE XII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, WAYNESBORO LOAM, STILLWATER, 1957.

Treatments 2/	Grams of oven dry hay per pot. 1/		
	2/6	4/1	Av. Total Yield
Check	1.17	4.43	5.60
P_1	1.60	5.50	7.10
K_1	1.13	4.13	5.26
P_1K_1	1.63	5.53	7.10
Ca_4	1.00	4.83	5.83
Ca_4P_1	1.60	4.93	6.53
Ca_4K_1	1.46	5.10	6.56
$Ca_4P_1K_1$	1.46	5.50	6.96
Mg_4	0.10	0.10	0.20
Mg_4P_1	0.46	1.96	2.42
Mg_4K_1	0.40	0.63	1.03
$Mg_4P_1K_1$	0.83	1.20	2.07
Ca_3Mg_1	1.26	4.03	5.30
$Ca_3Mg_1P_1$	1.96	5.23	7.19
$Ca_3Mg_1K_1$	1.36	4.63	5.99
$Ca_3Mg_1P_1K_1$	1.50	5.16	6.66
Ca_2Mg_2	1.33	3.56	4.89
$Ca_2Mg_2P_1$	1.53	4.40	5.93
$Ca_2Mg_2K_1$	1.36	4.06	5.42
$Ca_2Mg_2P_1K_1$	1.26	5.03	6.29

1/ Yield figures are the mean of three replications.
2/ See Table XI for details of treatments.

grams, was obtained from those plants grown in pots that received the $Ca_3Mg_1P_1$ treatment. Analysis of variance indicated significance among both the main treatment (calcium and magnesium rates and combinations) and sub-treatments (phosphorus and potassium levels) at the 1% level. Within sub-treatments the effects obtained from additions of phosphorus were highly significant at the 1% level. There was no significant interaction shown between main treatments and sub-treatments.

V SUMMARY AND CONCLUSIONS

The objective of these field and greenhouse experiments was to determine the differential response of alfalfa in yield and composition to various soil fertility treatments. Field experiments were conducted at three locations near Stillwater, Oklahoma, on Port loam, Port silty clay loam, and Norge fine sandy loam. Greenhouse studies were conducted on Port loam and Waynesboro loam.

Fertility studies used in the field experiments included different rates of phosphorus and potassium with and without boron applications. Studies in the greenhouse included different rates of calcium and magnesium with and without phosphorus and potassium applications.

Two alfalfa hay cuttings were taken from each of the field experiments in 1956. Forage samples from each fertility treatment were analyzed chemically for percentage nitrogen, phosphorus and potassium. Two hay cuttings were taken from the greenhouse experiments in 1957.

Results from the field experiments may be summarized as follows:

1. There was a significant linear yield response to potassium fertilization on Port loam soil.
2. There was a significant linear yield response to phosphorus fertilization on Port silty clay loam.

3. There was a significant response to boron fertilization on Norge fine sandy loam.
4. The highest total alfalfa hay yields on Port loam were obtained from those plots that received 80 pounds of phosphorus expressed as P_2O_5, 200 pounds of potassium expressed as K_2O, and 40 pounds of borax per acre. Plots that received 80 pounds P_2O_5 and 200 pounds of K_2O produced the highest total hay yield on Port silty clay loam. The highest total yield on Norge fine sandy loam was obtained from plots that received 40 pounds P_2O_5, 100 pounds K_2O and 40 pounds of borax per acre.
5. There was no consistent yield response apparent among the various trace element treatments in these experiments.

Results from the greenhouse experiment may be summarized as follows:

1. There was a significant response among both the main treatments (calcium and magnesium rates and combinations) and sub-treatments (phosphorus and potassium levels) on each soil type. Within sub-treatments the effects obtained from additions of phosphorus were highly significant on the Waynesboro loam soil. There was a significant interaction shown between the main treatments and the sub-treatments on the Port loam soil.

2. The highest yield on Port loam was obtained from pots that received 10 tons of $CaCO_3$ per acre. The highest yields on the Waynesboro loam were obtained from pots that received 7.5 tons of $CaCO_3$, 2.1 tons of $MgCO_3$ and 100 pounds P_2O_5 per acre. Those plants in pots that received 8.4 tons of $MgCO_3$ per acre produced the lowest total yield on both soil types.
3. Plant growth was inhibited on Waynesboro loam at the 8.4 tons of $MgCO_3$ per acre treatment. Application of 100 pounds P_2O_5 with 100 pounds K_2O per acre seemed to partially overcome the effect of this $MgCO_3$ treatment.

Figure 1. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Waynesboro Loam. (A) Check, (B) Mg_4, (C) Ca_4, (D) Ca_3Mg_1, (E) Ca_2Mg_2. See Table XI for Soil Treatments and Yields.

Figure 2. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Port Loam. (A) Check, (B) Mg_4, (C) Ca_4, (D) Ca_3Mg_1, (E) Ca_2Mg_2. See Table XI for Soil Treatments and Yields.

Figure 3. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Waynesboro Loam. (A) Check, (B) Mg_4, (C) Mg_4P_1, (D) Mg_4K_1, (E) $Mg_4P_1K_1$. See Table XI for Soil Treatments and Yields.

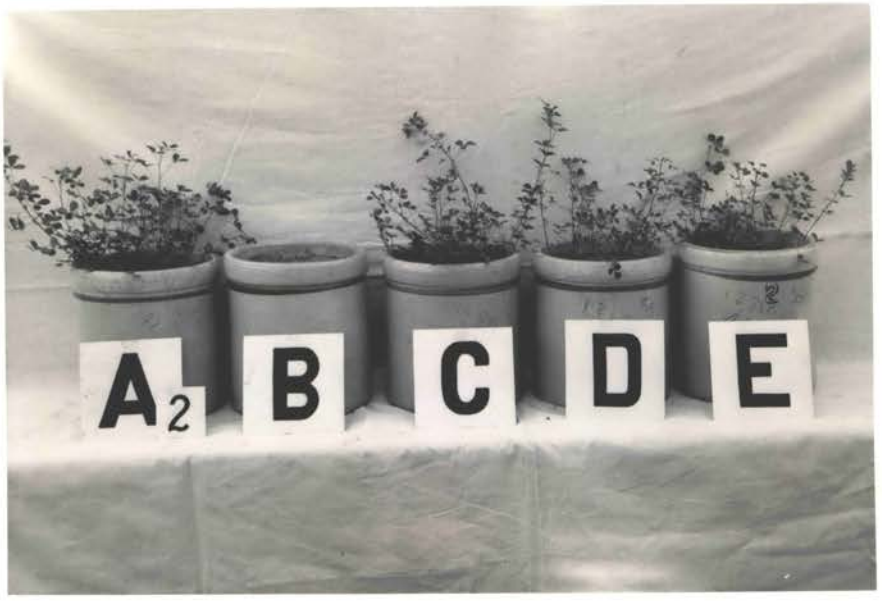

Figure 4. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Port Loam. (A) Check, (B) Mg_4, (C) Mg_4P_1, (D) Mg_4K_1, (E) $Mg_4P_1K_1$. See Table XI for Soil Treatments and Yields.

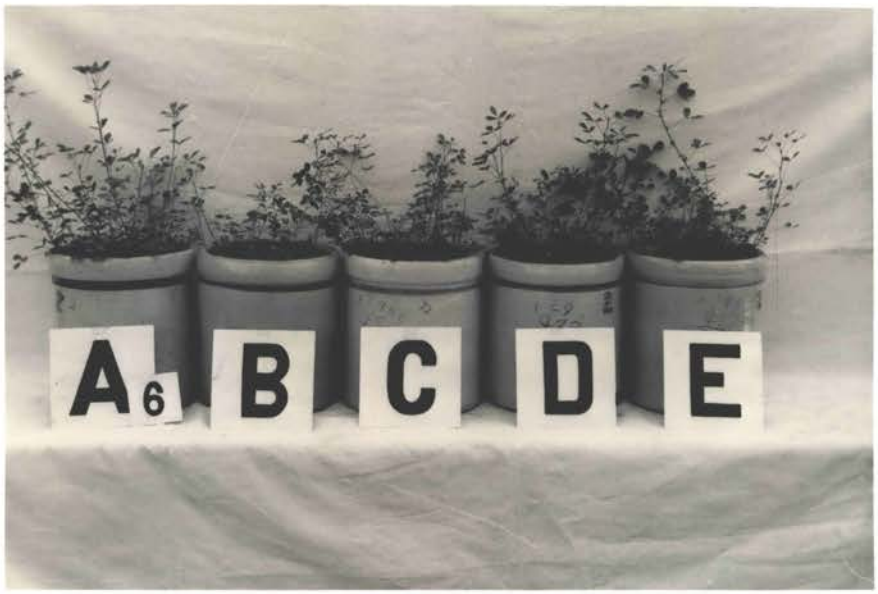

Figure 5. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Waynesboro Loam. (A) Check, (B) Ca_4, (C) Ca_4P_1, (D) $Ca_4P_1K_1$, (E) Ca_4K_1. See Table XI for Soil Treatments and Yields.

Figure 6. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Port Loam. (A) Check, (B) Ca_4, (C) Ca_4P_1, (D) Ca_4K_1, (E) $Ca_4P_1K_1$. See Table XI for Soil Treatments and Yields.

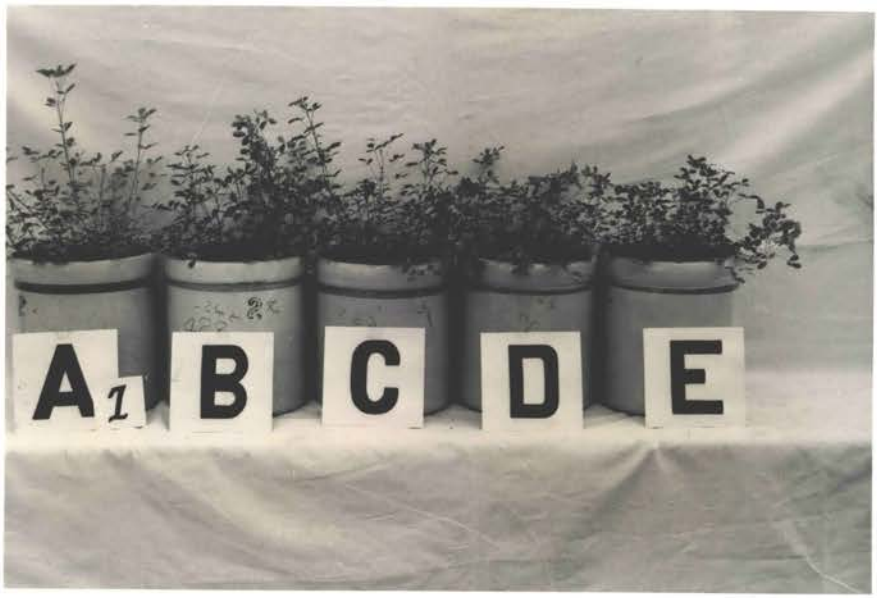

Figure 7. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Waynesboro Loam. (A) Check, (B) K_1, (C) P_1, (D) P_1K_1. See Table XI for Soil Treatments and yields.

Figure 8. Effect of Various Fertilizer Treatments on Growth of Alfalfa, Port Loam. (A) Check, (B) P_1, (C) K_1, (D) P_1K_1. See Table XI for Soil Treatments and Yields.

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VII APPENDIX

TABLE XIII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, STILLWATER, 1956.

Treatments [2]	Pounds of hay per plot [1] Rep 1	Rep 2	Rep 3	Total
Check	38.5	37.4	29.0	104.9
P_1	33.3	25.9	36.4	95.6
P_2	42.0	22.5	23.4	87.9
K_1	37.4	38.5	32.1	108.0
P_1K_1	30.8	30.3	43.8	104.9
P_2K_1	41.3	33.9	34.8	110.0
K_2	41.1	34.8	34.8	110.7
P_1K_2	30.6	31.3	35.5	97.4
P_2K_2	36.3	42.6	34.0	112.9
B	25.3	30.2	38.8	94.3
P_1B	30.4	18.3	28.6	77.3
P_2B	33.1	32.8	31.4	97.3
K_1B	25.1	32.9	35.0	93.0
P_1K_1B	42.2	33.1	33.8	109.1
P_2K_1B	41.4	42.0	34.4	117.8
K_2B	29.4	26.9	32.4	88.7
P_1K_2B	35.6	30.4	36.7	102.7
P_2K_2B	45.3	36.6	40.0	121.9

[1] Yield figures represent total hay yield for year 1956.
[2] See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	1744.99		
Reps	2	96.04	48.02	
Treatments	17	738.46	43.44	
P-level	2	113.27	56.64	
K-level	2	247.68	123.84	4.62*
Linear	1	164.48	164.48	6.41*
Quadratic	1	83.19	83.19	
B-level	1	16.89	16.89	
P X K	4	139.06	34.77	
P X B	2	151.25	75.63	
K X B	2	8.33	4.17	
P X K X B	4	61.98	15.50	
Error	34	910.49	26.78	

* Significant at 5% level.

TABLE XIV. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, STILLWATER, FIRST CUTTING, JUNE 12, 1956.

Treatments 1/	Pounds of hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	29.0	31.5	25.0	85.5
P_1	27.5	21.5	31.0	80.0
P_2	31.5	20.0	19.5	71.0
K_1	30.5	31.5	26.0	88.0
P_1K_1	27.5	25.5	32.0	85.0
P_2K_1	33.0	28.0	27.0	88.0
K_2	34.0	29.0	28.0	91.0
P_1K_2	27.0	26.5	28.0	81.5
P_2K_2	28.5	31.5	25.5	85.5
B	17.5	26.5	31.0	75.0
P_1B	23.0	15.0	24.0	62.0
P_2B	24.0	27.0	27.5	78.5
K_1B	21.5	26.5	26.0	74.0
P_1K_1B	33.0	26.0	28.5	87.5
P_2K_1B	31.0	34.5	27.5	93.0
K_2B	24.0	23.5	28.0	75.5
P_1K_2B	30.0	26.0	30.0	86.0
P_2K_2B	34.0	30.0	31.5	95.5

1/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	914.7		
Reps	2	19.8	9.9	
Treatment	17	422.8	24.87	
P-level	2	26.41	13.12	
K-level	2	148.2	74.1	5.338**
B-level	1	15.04	15.04	
P X K	4	54.6	13.65	
P X B	2	108.71	54.35	3.915*
K X B	2	11.85	5.93	
P X K X B	4	60.64	15.16	
Error	34	472.1	13.88	

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

TABLE XV. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, THOMAS FARM, PORT LOAM, SECOND CUTTING, JULY 21, 1956.

Treatments 1/	Pounds hay per plot Rep 1	Rep 2	Rep 3	Total
Check	9.5	5.9	4.0	19.4
P_1	5.8	4.4	5.4	15.6
P_2	10.4	2.5	3.9	16.8
K_1	6.9	7.0	6.1	20.0
P_1K_1	3.3	4.8	11.8	19.9
P_2K_1	8.3	5.9	7.8	22.0
K_2	7.1	5.8	6.6	19.5
P_1K_2	3.6	4.8	7.5	15.9
P_2K_2	7.8	11.1	8.5	27.4
B	7.8	3.7	7.8	19.3
P_1B	7.4	3.3	4.6	15.3
P_2B	9.1	5.8	3.9	18.8
K_1B	4.1	6.4	9.0	19.5
P_1K_1B	9.2	7.1	5.3	21.6
P_2K_1B	10.4	7.5	6.9	24.8
K_2B	5.4	3.4	4.4	13.2
P_1K_2B	5.6	4.4	6.7	16.7
P_2K_2B	11.3	6.6	8.4	26.3

1/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	272.57		
Reps	2	28.98	14.49	3.13
Treatments	17	82.77	4.87	
P-level	2	30.56	15.28	3.24
K-level	2	15.23	7.62	
B-level	1	.55	.55	
PK	4	27.56	6.89	
KB	2	3.08	1.54	
PKB	4	2.45	.61	
PB	2	3.28	1.64	
Error	34	160.88	4.73	

TABLE XVI. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, BLACKWELL LAKE STATION, PORT SILTY CLAY LOAM, STILLWATER, 1956.

Treatments 2/	Pounds of hay per plot 1/ Rep 1	Rep 2	Rep 3	Total
Check	31.8	41.0	47.0	119.8
P_1	38.7	40.5	55.0	134.2
P_2	38.4	41.0	45.5	124.9
K_1	40.0	45.5	50.0	135.5
P_1K_1	38.0	31.0	59.0	128.0
P_2K_1	40.6	32.0	78.0	150.6
K_2	39.3	36.0	63.0	138.3
P_1K_2	45.5	37.0	63.5	146.0
P_2K_2	37.0	34.5	81.5	153.0
B	34.6	30.5	35.5	100.6
P_1B	38.3	48.0	51.5	137.8
P_2B	37.7	40.0	44.5	122.2
K_1B	39.5	23.5	36.5	99.5
P_1K_1B	36.5	48.5	55.0	140.0
P_2K_1B	38.0	36.5	59.5	134.0
K_2B	38.3	28.0	48.5	114.8
P_1K_2B	37.0	43.5	63.5	144.0
P_2K_2B	42.8	37.5	63.5	143.8

1/ Yield figures represent total hay yield for year 1956.
2/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	7281.66		
Reps	2	3736.19	1868.10	29.02**
Treatment	17	1356.49	79.79	
P-level	2	540.08	270.04	4.19*
Linear	1	400.00	400.00	6.21*
Quadratic	1	140.08	140.08	
K-level	2	280.17	140.09	
B-level	1	162.24	162.24	
P X K	4	77.96	19.49	
P X B	2	237.26	118.63	
P X K X B	4	43.95	10.99	
K X B	2	14.83	7.41	
Error	34	2188.98	64.38	

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

TABLE XVII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, BLACKWELL LAKE STATION, PORT SILTY CLAY LOAM, STILLWATER, FIRST CUTTING, JUNE 11, 1956.

Treatments 1/	Pounds of hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	22.0	24.5	27.5	74.0
P_1	26.0	24.0	31.0	81.0
P_2	27.5	28.0	30.0	85.5
K_1	27.0	27.5	25.5	80.0
P_1K_1	25.5	20.5	27.0	73.0
P_2K_1	29.5	21.5	41.0	92.0
K_2	23.0	21.5	31.0	75.5
P_1K_2	31.5	23.0	29.0	83.5
P_2K_2	24.5	23.5	43.5	91.5
B	25.5	19.0	24.5	69.0
P_1B	27.5	24.5	28.0	80.0
P_2B	25.5	29.0	25.0	79.5
K_1B	24.0	17.0	22.5	63.5
P_1K_1B	24.0	26.5	26.5	77.0
P_2K_1B	26.5	26.0	27.5	80.0
K_2B	20.5	19.5	27.0	67.0
P_1K_2B	25.5	24.5	29.5	79.5
P_2K_2B	26.5	23.5	32.0	82.0

1/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	1085.08		
Reps	2	310.33	155.2	11.62**
Treatments	17	320.58	18.86	
P-level	2	185.17	142.59	10.67**
K-level	2	5.46	2.73	
B-level	1	63.38	63.38	4.74*
PK	4	17.83	4.46	
PB	2	28.70	14.35	
KB	2	4.85	2.42	
PKB	4	15.49	3.87	
Error	34	454.17	13.36	

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

TABLE XVIII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, BLACKWELL LAKE STATION, PORT SILTY CLAY LOAM, STILLWATER, SECOND CUTTING, JULY 18, 1956

Treatments 1/	Pounds of hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	9.8	16.5	19.5	45.8
P_1	12.7	16.5	24.0	53.2
P_2	10.9	13.0	15.5	39.4
K_1	13.0	18.0	24.5	55.5
P_1K_1	12.5	10.5	32.0	55.0
P_2K_1	11.1	10.5	37.0	58.6
K_2	16.3	14.5	32.0	62.8
P_1K_2	14.0	14.0	34.5	62.5
P_2K_2	12.5	11.0	38.0	61.5
B	9.1	11.5	11.0	31.6
P_1B	10.8	23.5	23.5	57.8
P_2B	12.2	11.0	19.5	42.7
K_1B	15.5	6.5	14.0	36.0
P_1K_1B	12.5	22.0	28.5	63.0
P_2K_1B	11.5	10.5	32.0	54.0
K_2B	17.8	8.5	21.5	47.8
P_1K_2B	11.5	19.0	34.0	64.5
P_2K_2B	16.3	14.0	31.5	61.8

1/ See Table III for detail of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	3598.77		
Reps	2	2005.73	1002.89	26.04**
Treatments	17	583.59	34.33	
P-level	2	162.56	38.51	
K-level	2	228.52	114.26	
B-level	1	22.81	22.81	
PK	4	37.82	9.46	
PB	2	120.85	60.43	
KB	2	2.76	1.38	
PKB	4	8.27	2.07	
Error	34	1309.45	38.51	

** Significant at 1% level.

TABLE XIX. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, STILLWATER, 1956. 1/

Treatments 2/	Pounds of hay per plot Rep 1	Rep 2	Rep 3	Total
Check	22.0	20.8	26.6	69.4
P_1	17.4	31.0	25.4	73.8
P_2	25.1	19.6	28.1	72.8
K_1	27.1	27.6	28.8	83.5
P_1K_1	20.4	27.9	25.7	74.0
P_2K_1	26.1	20.8	25.6	72.5
K_2	29.3	24.3	25.1	78.7
P_1K_2	21.5	27.6	27.5	76.6
P_2K_2	26.6	23.0	21.6	71.2
B	22.1	28.9	26.6	77.6
P_1B	28.3	27.5	28.8	84.6
P_2B	32.7	22.0	29.8	84.5
K_1B	24.1	29.5	30.7	84.3
P_1K_1B	25.9	33.5	27.4	86.8
P_2K_1B	27.5	23.0	29.5	80.0
K_2B	30.3	25.1	26.1	81.5
P_1K_2B	23.8	32.1	28.1	84.0
P_2K_2B	25.9	26.5	29.2	81.6

1/ Yield figures represent total hay yields for year 1956.
2/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	638.45		
Reps	2	33.32	16.66	
Treatment	17	167.38	9.85	
Phosphorus	2	8.75	4.38	
K-level	2	9.51	4.76	
B-level	1	97.06	97.06	7.54**
P X K	4	30.41	7.60	
P X B	2	3.61	1.81	
K X B	2	12.74	6.37	
P X K X B	4	5.29	1.32	
Error	34	437.75	12.87	

** Significant at 1% level.

TABLE XX. EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, STILLWATER, FIRST CUTTING, JUNE 13, 1956.

Treatments 1/	Pounds of hay per plot Rep 1	Rep 2	Rep 3	Total
Check	16.0	17.0	20.0	53.0
P_1	13.0	21.0	20.0	54.0
P_2	17.5	16.0	21.5	55.0
K_1	18.0	22.0	21.0	61.0
P_1K_1	16.0	21.5	19.5	57.0
P_2K_1	16.5	17.0	21.5	55.0
K_2	21.0	19.0	19.0	59.0
P_1K_2	18.5	21.5	20.5	60.5
P_2K_2	19.5	18.5	17.5	55.5
B	16.5	21.0	20.5	58.0
P_1B	19.0	22.0	22.0	63.0
P_2B	21.0	18.0	22.5	61.5
K_1B	18.0	22.0	23.0	63.0
P_1K_1B	16.5	23.5	22.0	62.0
P_2K_1B	17.0	18.5	23.0	58.5
K_2B	23.0	19.5	20.0	62.5
P_1K_2B	18.0	24.5	22.0	64.5
P_2K_2B	18.5	20.0	22.0	60.5

1/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	305.21		
Reps	2	86.34	43.17	9.833**
Treatments	17	69.54	4.09	
P-level	2	6.58	3.29	
K-level	2	9.34	4.67	
B-level	1	35.04	35.04	7.982**
PK	4	13.17	3.29	
PB	2	1.59	.785	
KB	2	3.11	1.56	
PKB	4	.71	.18	
Error	34	149.33	4.39	

** Significant at 1% level.

TABLE XXI. EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, PARADISE FARM, NORGE FINE SANDY LOAM, STILLWATER, SECOND CUTTING, JULY 22, 1956.

Treatments 1/	Pounds of hay per plot			
	Rep 1	Rep 2	Rep 3	Total
Check	6.0	3.8	6.6	16.4
P_1	4.4	10.0	5.4	19.8
P_2	7.6	3.6	6.6	17.8
K_1	9.1	5.6	7.8	22.5
P_1K_1	4.4	6.4	6.2	17.0
P_2K_1	9.6	3.8	4.1	17.5
K_2	8.3	5.3	6.1	19.7
P_1K_2	3.0	6.1	7.0	16.1
P_2K_2	7.1	4.5	4.1	15.7
B	5.6	7.9	6.1	19.6
P_1B	9.3	5.5	6.8	21.6
P_2B	11.7	4.0	7.3	23.0
K_1B	6.1	7.5	7.7	21.3
P_1K_1B	9.4	10.0	5.4	24.8
P_2K_1B	10.5	4.5	6.5	21.5
K_2B	7.3	5.6	6.1	19.0
P_1K_2B	5.8	7.6	6.1	19.5
P_2K_2B	7.4	6.5	7.2	21.1

1/ See Table III for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	53	194.74		
Reps	2	18.13	9.06	
Treatments	17	37.40	2.20	
P-level	2	.15	.075	
K-level	2	5.06	2.53	
B-level	1	15.46	15.46	3.78*
PK	4	5.52	1.38	
PB	2	5.87	2.94	
KB	2	.21	.105	
PKB	4	5.13	1.28	
Error	34	139.21	4.09	

* Significant at 5% level.

TABLE XXII. EFFECT OF VARIOUS SOIL FERTILITY TRACE ELEMENT TREATMENTS ON YIELD OF ALFALFA HAY, FIELD EXPERIMENT, STILLWATER, 1956.

Treatments [2]	Pounds of hay per acre at cutting date. [1] 6/12	7/21	Total Yield
Thomas Farm, Port loam			
Check	1191.0	910.3	2101.3
B	680.6	421.9	1102.5
Mg	884.8	801.4	1686.2
Mn	969.9	684.0	1653.9
S	986.9	772.5	1758.4
BMgMnS	1106.0	712.9	1818.9
Paradise Farm, Norge fine sandy loam			
Check	884.8	559.8	1443.6
B	816.7	667.0	1487.7
Mg	765.7	627.9	1393.6
Mn	901.8	568.3	1479.1
S	953.8	634.7	1570.3
BMgMnS	850.8	486.6	1337.4
Blackwell Lake Station, Port silty clay loam			
Check	1582.4	454.3	2036.7
B	986.9	411.8	1398.7
Mg	1531.4	294.4	1825.8
Mn	1582.4	347.1	1929.5
S	1650.5	396.4	2046.9
BMgMnS	1667.5	559.8	2227.3

1/ Yield figures represent the mean of three replications.

2/ Treatment symbols are:

Check = No fertilizer
B = 40 pounds borax per acre (11.3%).
Mg = 480 pounds epson salts per acre as $MgSO_4$.
Mn = 50 pounds per acre as $MnSO_4$.
S = 50 pounds per acre as Flowers of Sulfur.
BMgMnS = A combination of the above rates.

TABLE XXIII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, PORT LOAM, STILLWATER, 1957.

Treatments 2/	Grams oven dry forage per pot 1/ Rep 1	Rep 2	Rep 3	Total
Check	5.1	3.6	4.9	13.6
Ca_4	7.0	7.0	8.0	22.0
Mg_4	3.5	1.4	2.7	7.6
Ca_3Mg_1	6.5	6.0	6.7	19.2
Ca_2Mg_2	5.8	5.3	6.7	17.8
P_1	4.7	5.2	5.4	15.3
Ca_4P_1	6.7	7.3	7.2	21.2
Mg_4P_1	5.3	3.9	4.5	13.7
$Ca_3Mg_1P_1$	7.1	5.4	6.5	19.0
$Ca_2Mg_2P_1$	6.3	5.9	5.8	18.0
K_1	5.0	5.5	5.6	16.1
Ca_4K_1	6.8	7.7	7.3	21.8
Mg_4K_1	5.7	4.9	5.1	15.7
$Ca_3Mg_1K_1$	6.4	6.6	6.1	19.1
$Ca_2Mg_2K_1$	6.6	6.5	6.4	19.5
P_1K_1	5.6	3.9	5.8	15.3
$Ca_4P_1K_1$	6.7	6.2	6.4	19.3
$Mg_4P_1K_1$	4.0	4.7	4.3	13.0
$Ca_3Mg_1P_1K_1$	5.9	6.2	5.6	17.7
$Ca_2Mg_2P_1K_1$	5.7	6.7	6.2	18.6

1/ Each figure represents the combined dry forage yield from the two cuttings, 2/6/57 and 4/1/57.
2/ See Table XI for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	59	89.05		
Main Plot				
Treatments	4	60.53	15.133	37.18**
Error	10	4.07	.407	
Sub Plot				
Treatments	3	4.97	1.658	3.809*
P	1	.0201	.0201	
K	1	1.1481	1.1481	
P X K	1	3.8000	3.8000	8.763**
T X ST	12	10.5000	.857	
Error	30	13.05	.435	

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

TABLE XXIV. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, PORT LOAM, STILLWATER, FIRST CUTTING, FEBRUARY 6, 1957.

Treatment 1/	Grams oven dry forage per pot			
	Rep 1	Rep 2	Rep 3	Total
Check	1.7	1.6	1.8	5.1
Ca_4	1.7	1.8	1.7	5.2
Mg_4	0.6	.3	.5	1.4
Ca_3Mg_1	1.3	1.3	1.5	4.1
Ca_2Mg_2	1.2	1.5	1.4	4.1
K_1	1.3	1.6	1.5	4.4
Ca_4K_1	1.6	1.9	1.6	5.1
Mg_4K_1	1.3	1.1	1.1	3.5
$Ca_3Mg_1K_1$	1.2	1.6	1.6	4.4
$Ca_2Mg_2K_1$	1.3	1.4	1.7	4.4
P_1	1.4	1.8	1.2	4.4
Ca_4P_1	1.4	1.9	1.8	5.1
Mg_4P_1	0.7	0.4	0.8	1.9
$Ca_3Mg_1P_1$	1.3	1.0	1.3	3.6
$Ca_2Mg_2P_1$	1.5	1.4	1.4	4.3
P_1K_1	1.4	1.5	1.5	4.4
$Ca_4P_1K_1$	1.5	1.5	1.4	4.4
$Mg_4P_1K_1$	1.0	1.0	0.9	2.9
$Ca_3Mg_1P_1K_1$	1.0	1.2	0.9	3.1
$Ca_2Mg_2P_1K_1$	1.1	1.0	1.0	3.1

1/ See Table XI for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	59	7.86		
Main Plot				
Treatments	4	4.99	1.247	41.56**
Error	10	0.30	.03	
Sub-Plots				
Treatments	3	.5231	.1743	7.15**
P	1	.3375	.3375	13.84**
K	1	.0042	.0042	
P X K	1	.1814	.1814	7.44**
T X ST	12	1.3158	.1096	4.99**
Error	30	.7311	.02437	

** Significant at 1% level.

TABLE XXV. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, PORT LOAM, STILLWATER, SECOND CUTTING, APRIL 1, 1957.

Treatment 1/	Grams oven dry forage per pot			
	Rep 1	Rep 2	Rep 3	Total
Check	3.4	2.0	3.1	8.5
Ca_4	5.3	5.2	6.3	16.8
Mg_4	2.9	1.1	2.2	6.2
Ca_3Mg_1	5.2	4.7	5.2	15.1
Ca_2Mg_2	4.6	3.8	5.3	13.7
K_1	3.7	3.9	4.1	11.7
Ca_4K_1	5.2	5.8	5.7	16.7
Mg_4K_1	4.4	3.8	4.0	12.2
$Ca_3Mg_1K_1$	5.2	5.0	4.5	14.7
$Ca_2Mg_2K_1$	5.3	5.1	4.7	15.1
P_1	3.3	3.4	4.2	10.9
Ca_4P_1	5.3	5.4	5.4	16.1
Mg_4P_1	4.6	3.5	3.7	11.8
$Ca_3Mg_1P_1$	5.8	4.4	5.2	15.4
$Ca_2Mg_2P_1$	4.8	4.5	4.4	13.7
P_1K_1	4.2	2.4	4.3	10.9
$Ca_4P_1K_1$	5.2	4.7	5.0	14.9
$Mg_4P_1K_1$	3.0	3.7	3.4	10.1
$Ca_3Mg_1P_1K_1$	4.9	5.0	4.7	14.6
$Ca_2Mg_2P_1K_1$	4.6	5.7	5.2	15.5

1/ See Table XI for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	59	62.93		
Main Plots				
Treatments	4	40.479	10.119	25.297**
Error	10	4.000	.400	
Sub-Plots				
S-Treatments	3	3.691	1.230	5.083**
P	1	.170	.170	
K	1	1.121	1.121	4.636*
P X K	1	2.400	2.400	9.929**
T X ST	12	7.510	.625	2.586*
Error	30	7.250		

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

TABLE XXVI. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, WAYNESBORO LOAM, STILLWATER, 1957.

Treatments 2/	Grams oven dry forage per pot 1/ Rep 1	Rep 2	Rep 3	Total
Check	5.3	5.6	5.9	16.8
Ca_4	5.8	6.1	5.8	17.5
Mg_4	0.2	0.2	0.2	0.6
Ca_3Mg_1	5.0	5.3	5.6	15.9
Ca_2Mg_2	4.9	5.0	4.8	14.7
P_1	6.5	7.9	6.9	21.3
Ca_4P_1	5.6	6.6	7.5	19.7
Mg_4P_1	4.1	3.2	0.2	7.5
Ca_3Mg_1	7.2	7.2	7.2	21.6
Ca_2Mg_2	5.6	6.6	5.6	17.8
K_1	4.7	5.3	5.8	15.8
Ca_4K_1	6.8	6.0	6.9	19.7
Mg_4K_1	1.8	1.1	0.2	3.1
$Ca_3Mg_1K_1$	5.8	6.3	5.9	18.0
$Ca_2Mg_2K_1$	6.1	5.0	5.2	16.3
P_1K_1	6.8	6.9	7.3	21.0
$Ca_4P_1K_1$	6.9	7.5	6.5	20.9
$Mg_4P_1K_1$	1.4	3.4	1.4	6.2
$Ca_3Mg_1P_1K_1$	6.1	7.0	6.9	20.0
$Ca_2Mg_2P_1K_1$	5.4	7.7	5.8	18.9

1/ Each figure represents the combined dry forage yield from the two cuttings, 2/6/57 and 4/1/57.
2/ See Table XI for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	59	270.67		
Main Plots				
Treatments	4	218.90	50.725	59.327**
Error	10	8.55	.855	
Sub-Plots				
Treatments	3	23.92	7.973	10.463**
P	1	22.08	22.080	20.976**
K	1	.726	.726	
P X K	1	1.121	1.121	
T X ST	12	5.000	.417	
Error	30	22.850	.762	

** Significant at 1% level.

TABLE XXVII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, WAYNESBORO LOAM, STILLWATER, FIRST CUTTING, FEBRUARY 6, 1957.

Treatments 1/	Rep 1	Rep 2	Rep 3	Total
Check	1.0	1.1	1.4	3.5
Ca_4	0.8	1.0	1.2	3.0
Mg_4	0.1	0.1	0.1	0.3
Ca_3Mg_1	1.3	1.2	1.3	3.8
Ca_2Mg_2	1.2	1.4	1.4	4.0
K_1	1.0	1.2	1.2	3.4
Ca_4K_1	1.6	1.2	1.6	4.4
Mg_4K_1	0.1	1.0	0.1	1.2
$Ca_3Mg_1K_1$	1.4	1.3	1.4	4.1
$Ca_2Mg_2K_1$	1.5	1.3	1.3	4.1
P_1	1.3	1.8	1.7	4.8
Ca_4P_1	1.4	1.6	1.8	4.8
Mg_4P_1	1.4	0.1	0.1	1.6
$Ca_3Mg_1P_1$	1.9	2.0	2.0	5.9
$Ca_2Mg_2P_1$	1.9	1.5	1.2	4.6
P_1K_1	1.6	1.4	1.9	4.9
$Ca_4P_1K_1$	1.4	1.5	1.5	4.4
$Mg_4P_1K_1$	0.1	1.2	1.3	2.6
$Ca_3Mg_1P_1K_1$	1.6	1.7	1.2	4.5
$Ca_2Mg_2P_1K_1$	1.3	1.5	1.0	3.8

1/ See Table XI for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	59	18.05		
Main Plot				
Treatments	4	9.949	2.487	35.13**
Error	10	.7625		
Sub-Plots				
Treatments	3	2.0767	.6922	4.93**
P	1	1.768	1.768	12.729**
K	1	.0208	.0208	
P X K	1	.2801	.2801	
T X ST	12	1.2508	.1042	
Error	30	4.1659	.1389	

** Significant at 1% level.

TABLE XXVIII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF ALFALFA HAY, GREENHOUSE EXPERIMENT, WAYNES-BORO LOAM, STILLWATER, SECOND CUTTING, APRIL 1, 1957.

Treatments 1/	Rep 1	Rep 2	Rep 3	Total
Check	4.3	4.5	4.5	13.3
Ca_4	5.0	5.1	4.4	14.5
Mg_4	0.1	0.1	0.1	.3
Ca_3Mg_1	3.7	4.1	4.3	12.1
Ca_2Mg_2	3.7	3.6	3.4	10.7
K_1	3.7	4.1	4.6	12.4
Ca_4K_1	5.2	4.8	5.3	15.3
Mg_4K_1	1.7	0.1	0.1	1.9
$Ca_3Mg_1K_1$	4.4	5.0	4.5	13.9
$Ca_2Mg_2K_1$	4.6	3.7	3.9	12.2
P_1	5.2	6.1	5.2	16.5
Ca_4P_1	4.2	5.0	5.7	14.9
Mg_4P_1	2.7	3.1	0.1	05.9
$Ca_3Mg_1P_1$	5.3	5.2	5.2	15.7
$Ca_2Mg_2P_1$	3.7	5.1	4.4	13.2
P_1K_1	5.2	5.5	5.9	16.6
$Ca_4P_1K_1$	5.5	6.0	5.0	16.5
$Mg_4P_1K_1$	1.3	2.2	0.1	3.6
$Ca_3Mg_1P_1K_1$	4.5	5.3	5.7	15.5
$Ca_2Mg_2P_1K_1$	4.1	6.2	4.8	15.1

1/ See Table XI for details of treatments.

Analysis of Variance

Source	DF	SS	MS	F
Total	59	176.77		
Main Plot				
Treatment	4	141.954	35.488	53.102**
Error	10	6.683	.6683	
Sub-Plots				
Treatments	3	12.289	4.289	7.389**
P	1	12.060	12.060	20.779**
K	1	.580	.580	
P X K	1	.228	.228	
T X ST	12	4.534	.3778	
Error	30	17.414	.5804	

** Significant at 1% level.

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Master of Science

Thesis: EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS ON ALFALFA YIELD AND COMPOSITION WITH EMPHASIS ON CALCIUM AND MAGNESIUM RATIOS

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