THE EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD AND COMPOSITION OF ALFALFA ON TWO SOIL TYPES

By

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THE EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS

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I INTRODUCTION

The importance of alfalfa to Oklahoma agriculture is reflected in the increasing acreage within the state and this crop's large contribution to the farm cash income (1).[1] Problems of soil fertility and management are basic to successful establishment and maintenance of this perennial legume. The high plant nutrient requirements of alfalfa are well recognized (2).

A comprehensive research study has been initiated at the Oklahoma Agricultural Experiment Station concerning the soil fertility requirements for alfalfa grown on representative soil types within the state. The study herein reported had the objective of determining the effects of various soil fertility treatments on the yield and composition of alfalfa on Waynesboro loam and Port loam soils. Studies included both field and greenhouse experiments concerned with differential fertilizer treatments of phosphorus, potassium, boron, manganese and sulfur.

[1]Figures in parenthesis refer to literature cited.

II REVIEW OF LITERATURE

Alfalfa is tolerant to a wide range of soil conditions (19). However, different responses to management and fertility practices are frequently encountered, on various soils, in different climatic regions. This crop has high requirements for calcium and magnesium and apparently requires a soil pH of 6.5 or higher for best growth (3). Woodhouse (52), in North Carolina, concluded from experiments 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.

Schmehl, et al. (42) studied the influence of soil acidity on the absorption of calcium by alfalfa using radio-calcium. They reported the rate of absorption of calcium by alfalfa was markedly reduced in the presence of aluminum ions and to a lesser degree, manganese and hydrogen ions in the nutrient solution. The low calcium content usually observed in plants grown on an acid soil may be due to the antagonistic effect of aluminum, manganese, and hydrogen ions on the absorption of calcium ions rather than the low supply of calcium in the soil.

Winter survival of alfalfa is closely related to soil fertility. Wang, et al. (50) 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 plant. This capacity for retention of water appears to be directly related to the ability of alfalfa to withstand winter killing.

Hunter (22) found no relationship between the calcium - magnesium ratio and yield. Variations in the calcium - magnesium ratio ranged from 1-4 to 32-1, values both higher and lower than those normally found in soils.

Alfalfa uses relatively large amounts of phosphorus. Only a part of the phosphorus fertilizers added to the soil as available phosphorus is used by the plant (30). Nielson (37), reporting on work done in Utah, indicates that time of application of phosphate is not critical. Fall applications appear to be equally effective as spring treatments. Burning may result if there is an appreciable amount of vegetative growth. Woodhouse (52) found that alfalfa has a high requirement for phosphorus during the time it is becoming established.

A residual effect can be expected from applications of phosphate. Several investigators (11), (27) have shown that the residual effect of rock phosphate may last for several years, while superphosphate may not have as much residual effect. Larson, et al. (23) found that yields of oats and alfalfa were markedly increased by phosphate fertilizer. For the first two crop yields, the yields followed a curve of diminishing returns. Later, however, the first increment of 30 pounds of P_2O_5 per acre became ineffective. During the first two years of the experiment a corresponding increase in phosphorus in the plant to the phosphate applied was found.

Dennis and Chesnin (10) reported phosphate treatments increased the yield and influenced the composition of alfalfa on four Eastern Nebraska soils. The total nitrogen, phosphorus, and magnesium uptake was increased with phosphate applications. Phosphate tended to decrease the uptake of calcium. Hunter (22) concluded that the level of available phosphorus in the soil was the most important factor affecting the phosphorus content on alfalfa.

Seay, et al. (44) found a linear relationship between the percentage of potassium contained in the alfalfa and the logarithm of the number of pounds of exchangeable potassium per acre in the soil on which the crop was grown. Alfalfa tends to consume potassium in excessive amounts known as luxury consumption. Brown, et al. (7), in studies of potassium and boron fertilization of alfalfa on some Connecticut soils, found that large applications of K_2O, before planting, produced alfalfa with a high potassium content and low calcium content the first year, but this was reversed the third year. This treatment also resulted in poorer stands than where the treatments were divided into annual or more frequent applications. All treatments increased yields. Woodhouse (52) found that applications of potassium aided in stand maintenance of alfalfa and decreased the number of weeds over the plots receiving no potash.

Chandler, et al. (8) found the potassium content of alfalfa to be a reliable criteria for predicting the need of potassium fertilization of alfalfa. When the potassium content of the alfalfa at the 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.

For years fertility studies have had to do with nitrogen, phosphorus, potassium, and lime. In many instances, the trace elements are the first limiting factor (25), (2), (20). Boron has been studied to a greater extent than any of the trace elements (2).

The exact function of boron in plants is not known. The concentration range between the minute amount necessary for plant growth and that which is toxic is relatively narrow. Wolff (51) found that applications of five to ten pounds of borax per acre overcame boron deficiencies in cauliflower, but 20 pound applications resulted in toxicity to the plants. Muhr (32) obtained yield increases in soybeans with applications of boron until the boron content of the plant reached 30 p.p.m. on a dry weight basis. Toxic effects were obtained when the boron content exceeded 50-60 p.p.m.

According to Stinson (47) there apparently is a positive relationship between maturity, productivity level, and water-soluble boron of soils. He found boron to be an aid in cell division, especially in young, rapidly growing tissue. Therefore, a sharp reduction in available boron in the soil may result in deficiency symptoms at the regions of cell division or terminal parts of the plants. Brown et al. (6) decreased boron deficiency symptoms and increased flowering of alfalfa by additions of borax, but yields were not effected. Dawson and Gustafson (9) found that boron deficiency symptoms appeared before yields were reduced by the deficiency. They gave as criteria for determining the need for boron fertilization: (a) critical water-soluble boron content of soil was .35 micro-gram per gram of air-dry soil. (b) 20 micro-gram of boron per gram of oven-dry hay.

Although much work has been done on the study of the relationship between boron availability and soil conditions, little is known about the activity of this element in the soil. The soil conditions that have received considerable attention are: moisture content, soil reaction, organic matter content, biological activity, nutrient balance and isomorphous substitution.

Brown and King (6), working with a glacial till soil in Connecticut, found two soil conditions under which boron deficiency was most likely to occur. These are: low moisture content and an alkaline reaction. Dregne and Powers (14) concluded that the duration of treatment of the soil with boron fertilizers would vary with the climate, soil, crop yield, rate of application and other factors.

Parks and Shaw (39) and Dregne and Powers (14) reported deficiency symptoms in plants sensitive to boron shortages are much more pronounced in dry seasons than in seasons with adequate rainfall. Brown and King (6) reported that boron deficiency was due to a very dry season. Dregne and Powers (14) found that irrigation increased the boron content of alfalfa, probably by increasing its availability or liberation.

Calcium and magnesium form insoluble borates at a high pH but not in a soil with an acid reaction. Midgeley and Dunklee (31) found that, in general, the ability of soils to fix boron was dependent on the degree of acidity and extent to which they were limed. Naftel (34) found that liming decreased the water-soluble boron content of the soils directly in proportion with the amount of lime applied. Parks and Shaw (39) found boron fixation to be favored by reactions above neutrality. Lynd and Turk (24) found that overliming injury was not prevented or corrected by the addition of boron to the soil.

Nutrient balance, especially concerning calcium and magnesium, is closely associated with soil reaction and boron fixation. Muhr (32) reduced the boron content of soybeans by additions of carbonates and sulfates of calcium and magnesium, even on soils receiving excessive amounts of borax. Applications of sodium carbonate and sodium sulfate had no effect upon the boron content of the plant. Drake, et al. (13)

found that boron deficiency was due to the calcium boron ratio and not to the active calcium in the soil.

Experiments indicate that boron contained in the plant residue becomes available to plants as the material is decomposed (38). Berger and Truog (4) found that the organic matter content of the soil exerted a greater influence on boron availability in acid soils than did pH. However, the reverse was true for soils of an alkaline reaction. Drake, et. al. (13) stated that boron is not absorbed by the humus complexes.

Preliminary studies with soil cultures in the incubator (35), (36) showed that the water-soluble boron was much higher in sterilized cultures than in similar cultures not sterilized. Midgley and Dunklee (31) stated that the available evidence definitely indicates that borate fixation in soils is chemical rather than biological in nature.

Parks and Shaw (39) point out the possibility of boron substituting for aluminum in alumino-silicates. This, however, would result in a less stable particle because the boron ion is not as large as the aluminum ion and would not be held as firmly. They also point out that the presence of calcium ions, among the other factors, tends to increase the boron content of precipitates of silicon and aluminum. This lends support to the possibility that boron enters, in small amounts, into complexes of calcium alumino-silicate products.

Manganese deficiency commonly occurs on soils of high pH and of high organic matter content (18). Lynd and Turk (24) found that with increasing rates of lime there was a marked decrease in exchangable manganese. Garey and Barber (18) found evidence that oxidation of forms of sulfur or acid production are important for manganese to become available from unavailable forms. Vavra and Fredrick (49) 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. They also found that addition of calcium carbonate caused a decrease in the amount of soluble manganese released, although the amount of sulfate formed was not changed significantly. Evans and Purvis (16) found that, under treatments of manganese sulfate, chlorosis in plants began to disappear within three days after application. Treated plots gave a yield increase of 87 percent over untreated plots. Plant analysis from the plots showed the iron/manganese ratio was very wide on the untreated plots. They point out the possibility that the chlorosis was due to an iron toxcity which was counteracted by the manganese.

Haddock and Vandecaveye (20), using two Western Washington soils, received none to slight yield reponse from manganese fertilization. Sulfur appeared to be the first limiting element on these soils. Bear (3) reported a marked increase in yields of crops, especially legumes, has been obtained by additions of sulfur fertilizers in many areas of the United States. Bear (2) also points out that sulfur is supplied in sufficient quantities by plant material and rainfall in most areas especially around industrial centers.

Investigations have shown that alfalfa requires high fertility for good yields. Lime should be applied to soils with a low pH. Best results were obtained by mixing the lime with the plow layer of the soil. Absorption of calcium may be related to the presence of aluminum ions and also to manganese or hydrogen ions.

Winter hardiness and stand maintenance of alfalfa are closely related to soil fertility. Additions of lime and other fertilizers aid alfalfa in withstanding the low temperatures of Northern United States by increasing the water-soluble protein content in the plant.

Phosphate fertilizer treatments increase the uptake of nitrogen, phosphorus and magnesium, while at the same time calcium uptake is decreased.

Large applications of potash are depleted rather rapidly. Applications of K_2O should be made for annual or shorter periods of consumption. The critical level of exchangeable potassium in the soil is approximately 80 pounds per acre. Response to K_2O fertilizer may be expected if the potassium content of the plants is less than 1.25 percent at the early bloom stage.

Boron deficiency symptoms occur before a significant yield decrease is found. Applications of borax to boron deficient soil will decrease boron deficiency symptoms and induce flowering. Boron deficiencies commonly occur on heavily limed soil or sandy textured soil. The moisture content of the soil is related to the availability of boron, dry soils tending to reduce the amount of available boron.

Sulfur is the first limiting element in some of the Western Washington soils but is not commonly thought to be lacking in the Mid-West or Southwest.

Soils most likely to be deficient in manganese are of high pH. Manganese is closely associated with iron. A toxicity from iron may result in a manganese deficiency. Large yield increases may be obtained on manganese deficient soils by additions of manganous sulfate.

III SOILS USED IN THE GREENHOUSE EXPERIMENT

The soils used in this experiment were Port loam and Waynesboro loam. Some physical and chemical characteristics of the soils are shown in Table 1. The Port loam was chosen because it is representative of the deep, well drained, medium textured soils commonly used for alfalfa production in central Oklahoma. The Waynesboro was selected from an area where previous investigation (33) had shown a response to boron fertilization.

Port Loam

A bulk sample from the plow layer, 0-6" depth, of Port loam soil was taken from the Thomas farm about $2\frac{1}{2}$ miles east of Stillwater, Payne County, Oklahoma. The approximate location of the sampling site was 500 yards south and 100 yards east of the northwest corner of the farm which is located in the $NW\frac{1}{4}$ $NE\frac{1}{4}$ Sec. 20, Twp. 19N; R 3E.

This soil was formed from parent material of alluvial origin and is located on an occasionally inundated flood plain. This soil has a brown loam topsoil about 16 inches in depth; it has a medium granular structure and friable consistence over calcareous reddish brown material. A detailed description of this soil series is found in the Manual of Soil Series of Oklahoma (26).

The land from which this soil was taken, had been in continuous corn since 1948 and had not received any lime during that time. This may account for the low pH, shown in Table 1.

Waynesboro Loam

A bulk sample from the plow layer, 0-6" depth, of Waynesboro loam soil was taken from the Southeastern Oklahoma Soil Improvement Station which is located about $2\frac{1}{2}$ miles north of Heavener, LeFlore County, Oklahoma. The sampling location was about 150 yards west and 100 yards south of the Community Building located in the $N\frac{1}{2}$ $NW\frac{1}{4}$ Sec. 7, Twp. 5N; R 26E.

A detailed description of this soil may be found in the Report of Soil Survey (17). "In general this soil has a brown loam surface five to eight inches in depth over a yellowish-red clay loam subsoil which is mottled with red in the lower part and becomes brownish and 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 chemical and physical analyses of these two soils are presented in Table 1. Mechanical analysis was made by the hydrometer method essentially as presented by Bouyoucos (5). Available phosphorus was determined by leaching with .1 normal acetic acid essentially as proposed by Harper (21). Exchange capacity and exchangable potassium were determined essentially by the procedures presented by A.O.A.C. (28), using neutral normal ammonium acetate as the extracting agent. Total nitrogen was determined by a modification of the Kjeldahl method (41). The percentage organic matter was determined by the procedure outlined by Schollenberger (43). Soil reaction was determined by the method presented by Peech and English (40), using the Beckman glass-electrode potentiometer.

(1) Taken from Galloway (17).

Table 1. 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	1.421	1.365
Percent nitrogen	.0767	.0690
Available phosphorus (pounds per acre)	21.76	16.96
Exchangeable potassium (pounds per acre)	204	145
Cation exchange capacity (meq./100 gms.)	7.96	7.56

IV EXPERIMENTAL PROCEDURE

Field Experiments

The field experiments reported in this study were conducted on two contrasting soil types, a Port loam and a Waynesboro loam.

The plots on the port loam were located on the Thomas farm, about $2\frac{1}{2}$ miles east of Stillwater, Payne County, Oklahoma, on State Highway 51, in the NW$\frac{1}{4}$ NW$\frac{1}{4}$ Sec. 20, Twp. 19N; R 3E. This experiment was started on an established stand of alfalfa in February of 1955 and included annual applications of the following treatments:

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

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

K_1 = 100 pounds K_2O per acre as KCl (60%)

K_2 = 200 pounds K_2O per acre as KCl (60%)

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

The plots were laid out as a complete factorial design having all possible combinations of the above treatments with three replications. Three hay cuttings were obtained in 1955 and yields are presented in Table 25.

The fertility studies on the Waynesboro loam were conducted at the Southeastern Oklahoma Soil Improvement Station located about $2\frac{1}{2}$ miles north of Heavener, LeFlore County, Oklahoma. This experiment was established in September, 1953, as a randomized block, split-plot design with three replications and included the following treatments:

R_1 = 750 pounds rock phosphate (33% total P_2O_5) per acre

R_2 = 1500 pounds rock phosphate (33% P_2O_5) per acre

P_1 = 250 pounds super phosphate (20% P_2O_5) per acre

P_2 = 500 pounds super phosphate (20% P_2O_5) per acre

K_1 = 100 pounds KCl (60% K_2O) per acre

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

Mg = 400 pounds magnesium sulfate (9.87% Mg) per acre

S = 50 pounds sulfur per acre

BMgS = All the above three trace elements

The rock phosphate was applied once, at the time of establishment. All other treatments were applied at the time of establishment and annually thereafter. Yields were not taken during 1954 due to an uneven stand and a large number of volunteer plants in the plots. Three hay cuttings were obtained in 1955, yields are presented in Table 26.

Greenhouse Experiment

The objective of the greenhouse experiment was to determine the effects of two phosphorus and potassium levels, with and without, boron, manganese, sulfur, and a mixture of these latter three 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 screen and air-dried. Both soils were limed at the rate of four tons of lime per acre. The liming material consisted of 85% C.P. grade calcium carbonate ($CaCO_3$) and 15% C.P. grade magnesium carbonate ($MgCO_3$).

Eight kilograms of limed soil from each soil type were weighed into a sufficient number of two-gallon, glazed, earthenware pots to enable all treatments to be made in triplicate. There were three replications on each soil of each of the twenty treatments, making a total of 120 pots.

The treatments were designated as follows:

Check	K_1	P_1	K_1P_1
B	K_1B	P_1B	K_1P_1B
	K_1Mn	P_1Mn	K_1P_1mn
S	K_1S	P_1S	K_1P_1S
BMnS	K_1BMnS	P_1BMnS	K_1P_1BMnS

Symbols:

K_1 = 200 pounds K_2O per acre as KCl (C.P.)

P_1 = 400 pounds P_2O_5 per acre as $Ca(H_2PO_4)_2 \cdot H_2O$ (C.P.)

B = 50 pounds boron per acre as H_3BO_4 (C.P.)

Mn = 50 pounds manganese per acre as $MnSO_4 \cdot H_2O$ (C.P.)

S = 100 pounds sulfur per acre as flowers of sulfur

BMnS = Mixture of the three trace elements.

All elements, excepting sulfur, were applied in solution.

The soils were planted to certified Buffalo alfalfa, Medicago sativa, October 7, 1955. Before planting, the seeds were allowed to soak for a period of 26 hours in a mixture of innoculum, Rhizobium species, and water. The seeds were planted in circular rows within each pot and covered to a depth of ½ inch. Following germination, the number of seedling plants was adjusted to 10 per pot.

The first cutting was harvested March 12, 1956. Subsequent cuttings were harvested April 7, 1956, and May 12, 1956. The plant material was dried in the oven at 65°C. and weighed; then ground for later chemical analyses. Yields from the Port loam soil are presented in Table 7. Yields from the Waynesboro loam soil are presented in Table 15.

Chemical determinations made on the plant material included total nitrogen, phosphorus, and potassium. Nitrogen was determined by the Kjeldahl method (41) and results are presented in Table 9 and 17. The plant materials were prepared for phosphorus and potassium analyses by using a modification of the nitric-perchloric wet digestion method as outlined by Piper (41). Phosphorus was determined by developing phosphomolybdenum blue with hydrazine sulfate essentially according to Piper (41). Results are presented in Tables 11 and 19. Potassium was determined by use of the Perkin-Elmer Flame Photometer essentially according to the method of Piper (41). Results are presented in Tables 13 and 21.

Statistical Analysis

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

Data were subjected to analysis of variance according to Snedecor (45) to determine significant differences. Coefficient of variation and standard error of mean were determined according to Snedecor (45). Where differences occured in the analysis of variance, a Multiple Range test was made on the data using the standard error of the mean according to Duncan (15).

V RESULTS AND DISCUSSION

This study was concerned with alfalfa hay yield and composition as affected by various soil fertility treatments on two different soils. Results were obtained from two field experiments and a greenhouse experiment.

Field Experiments

Port loam. Yields from three alfalfa hay cuttings during 1955 from this experiment are shown in Tables 2 and 25. Analysis of variance and coefficient of variation are shown in Table 3, and a Multiple Range test is shown in Table 4. Lowest total yield, 4098 pounds per acre, was obtained from the check (no treatment) plots. Highest total yield, 5070 pounds per acre, was obtained with the P_2K_1 treatment. Analysis of variance indicated significance between fertilizer treatments at the 5 percent probability level. There was a significant linear response, at the 5 percent level, to phosphorus fertilization at the three rates used. A quadratic response to potassium fertilization is indicated at the three rates used although response was not significant. There was no significant interaction between the various fertility treatments including boron.

Waynesboro loam. Three alfalfa hay cuttings were taken from this field experiment in 1955 and yields are shown in Tables 5 and 26. The lowest total yield, 627 pounds per acre, was obtained from the P_2 plots. Highest total yield, 2633 pounds per acre, was obtained from the R_1P_1MgK treatment. The analysis of variance, Table 6, indicated a significant

Table 2. Effect of various soil fertility treatments on yield of alfalfa hay in the field experiment, Port loam, Thomas farm, Stillwater, 1955.

Treatment**	Pounds of hay per acre at cutting date.* 6/10	7/14	11/1	Average
Check	2155	1489	454	4098
P_1	2212	1574	716	4502
P_2	2297	1758	837	4892
K_1	2212	1659	489	4360
P_1K_1	2269	1695	702	4665
P_2K_1	2326	1843	901	5070
K_2	2255	1475	539	4268
P_1K_2	2297	1560	667	4524
P_2K_2	2212	1787	893	4892
B	2198	1595	638	4431
P_1B	2070	1624	780	4474
P_2B	2326	1744	801	4871
K_1B	2099	1602	560	4261
P_1K_1B	2439	1815	773	5027
P_2K_1B	2354	1865	787	5006
K_2B	2226	1503	525	4254
P_1K_2B	2524	1680	709	4914
P_2K_2B	2297	1751	752	4800

* Yield figures are the mean of three replications.
** Treatment symbols are:
Check = no fertilizer
P_1 = 40 pounds P_2O_5 (0-45-0) per acre
P_2 = 80 pounds P_2O_5 (0-45-0) per acre
K_1 = 100 pounds K_2O (KCl) per acre
K_2 = 200 pounds K_2O (KCl) per acre
B = 40 pounds borax (11.3% B) per acre

Table 3. Summary of analysis of variance, treatment breakdown, coefficient of variation, and standard error of means for alfalfa hay yield, field experiment, Port loam[(1)]

Analysis of Variance

Source	df	SS	MS	F
Total	53	8128.26		
Replications	2	3050.03	1525.0150	
Treatments	17	2740.26	161.1918	2.34*
Error	34	2337.97	68.7638	

Treatment breakdown

Source	df	SS	MS	F
P	2	2101.79	1050.90	15.28*
Linear	1	2055.11	2055.11	29.89*
Quadratic	1	46.68	46.68	
K	2	179.15	89.58	1.30
Linear	1	20.25	20.25	
Quadratic	1	158.90	158.90	2.31
B	1	54.00	54.00	
PK	4	113.07	28.27	
PB	2	112.53	56.26	
KB	2	1.33	0.66	
PKB	4	178.39	44.60	
Error	34	2337.97	68.76	

* Significant at the 5% probability level.

Coefficient of variation = 8.47%

Standard error of mean for P_0, P_1, P_2, K_0, K_1, K_2 = 1.9545
Standard error of mean for B_0 and B_1 = 1.5959
Standard error of mean for all treatments = 4.7876

(1) Analyses were calculated on pounds per plot bases.

Table 4. Multiple range test at the 5% level of treatment means of the yield of alfalfa hay on Port loam soil in the field experiment, 1955.

Treatment means ranked in order of magnitude.

Check	K_2B	K_1B	K_2	K_1	B	P_1B	P_1	P_1K_2	P_1K_1	P_2K_2B	P_2B	P_2	P_2K_2	P_1K_2B	P_2K_1B	P_1K_1B	P_2K_1
4098	4254	4261	4268	4360	4431	4474	4502	4524	4665	4800	4871	4892	4892	4914	5006	5027	5070
					—	—	—	—	—	—	—	—	—	—	—	—	—
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	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
—	—	—	—	—	—	—	—	—	—								

Any two means not underscored by the same line are significantly different at the 5% level of significance.
Any two means underscored by the same line are not significantly different at the 5% level of significance.

difference in yields with application of the potassium treatment at the 5 percent probability level. There was no significant interaction in the potassium vs. other fertilizer treatments. The yield from plots receiving the R_1P_1BMgS treatment, as shown by the Multiple Range test, Table 6, was significantly higher, at the 5 percent level, than plots receiving the P_2 and R_2 treatments. The thin stands of alfalfa on two replications of the P_2, R_2, R_1P_1Mg and R_1P_1 treated plots was believed to contribute to lower yields than would be expected as a result of the soil fertility treatments.

Greenhouse Experiment

Port loam. The results from chemical analyses of this soil, shown in Table 1, indicated a low supply of available phosphorus, and nitrogen. The soil pH was much lower than that proposed by Bear (3) as being necessary for optimum growth of this crop. The analyses indicated an adequate supply of exchangable potassium in accordance with a critical level of this element, as proposed by Chandler, et. al. (8).

Three cuttings of alfalfa hay were obtained from this soil in the greenhouse experiment and the dry weight yields are shown in Tables 7, 27, 28 and 29. An analysis of variance, coefficient of variation and Multiple Range test are shown in Table 8. The highest average yield, 11.37 grams, was obtained from the K_1P_1 treated pots and the lowest average yield, 8.67 grams, was obtained from the pots receiving K_1Mn treatment. The analysis of variance indicated a difference in yield due to fertilizer treatments, significant at the 1 percent level. The K_1P_1B, K_1P_1Mn and K_1P_1 treatments produced similar yields but produced significantly higher yields than did treatments K_1Mn, P_1B and B. Yield from P_1 treated pots was significantly higher than the yield from the K_1Mn

Table 5. Effect of various soil fertility treatments on yield of alfalfa hay in the field experiment, Waynesboro loam, Heavener, 1955.

Treatment**	Pounds of hay per acre at cutting date.* 6/28	8/31	10/25	Total
Check	390	563	40	993
K	711	736	494	1941
P_1	514	533	178	1225
P_1K	825	874	524	2223
P_2	336	291	0	627
P_2K	578	929	558	2065
R_1	687	696	316	1699
R_1K	998	874	568	2440
R_2	346	306	94	746
R_2K	805	771	514	2089
R_1P_1	385	484	94	963
R_1P_1K	825	889	504	2218
R_1P_1B	351	558	227	1136
R_1P_1BK	835	864	464	2163
R_1P_1Mg	415	385	99	899
R_1P_1MgK	904	1037	692	2633
R_1P_1S	821	651	212	1685
R_1P_1SK	938	1062	627	2628
R_1P_1BMgS	825	741	301	1867
R_1P_1BMgSK	1166	948	474	2588

* Yield figures are the mean of three replications.

** Treatment symbols are:

Check = no fertilizer
K = 100 pounds KCl (60% K_2O) per acre
P_1 = 250 pounds super phosphate (20% P_2O_5) per acre
P_2 = 500 pounds super phosphate (20% P_2O_5) per acre
R_1 = 750 pounds rock phosphate (33% total P_2O_5) per acre
R_2 = 1500 pounds rock phosphate (33% total P_2O_5) per acre
B = 40 pounds borax (11.3% B) per acre
Mg = 400 pounds magnesium sulfate (9.87% Mg) per acre
S = 50 pounds flowers of sulfur per acre

Table 6. Summary of analysis of variance, coefficient of variation, standard error of mean and Multiple Range test for alfalfa hay yield, field experiment, Waynesboro loam [1]

Source	df	SS	MS	F
		Analysis of Variance		
Total	59	2084.39		-
Replications	2	347.81		
K	1	864.12	864.12	73.89*
Error	2	23.39	11.695	
Treatments	9	231.15	25.683	1.663
K X treatments	9	61.97	6.885	.45
Error	36	555.96	15.443	

* Significant at the 1 percent probability level.

Coefficient of variation = 32.94 %

Standard error of treatment mean = 2.687

Multiple Range test

Treatment means ranked in order of magnitude.

P_2	R_2	R_1P_1 Mg	R_1P_1	Check	R_1P_1 B	P_1	R_1P_1 S	R_1	R_1P_1 BMgS	K	P_2 K	R_2 K	R_1P_1 BK	R_1P_1 K	P_1 K	R_1 K	R_1P_1 BMgSK	R_1P_1 SK	R_1P_1 MgK
627	746	899	963	993	1136	1225	1685	1699	1867	1941	2065	2089	2163	2218	2223	2440	2588	2628	2633

Any two means not underscored by the same line are significantly different at the 5% probability level.
Any two means underscored by the same line are not significantly different at the 5% probability level.

(1) Analyses were calculated on pounds per plot bases

treatment but similar to yields from P_1B and B treated pots. There was no significant difference in yields due to treatment interaction. The rate of boron application used was apparently too high. A boron toxicity, which caused difficulty in getting plants established, was noticed on all boron treated pots after emergence and until the first cutting was removed. This apparent toxicity was observed again after the third cutting was removed.

Chemical determinations of the forage produced in this experiment included percentages of nitrogen, phosphorus and potassium. Results of these analyses are shown in Tables 9, 11, and 13.

The forage containing the highest percentage nitrogen, 3.72 percent, was produced on pots receiving the P_1B treatment and the lowest content of nitrogen, 3.33 percent, was found in the forage produced on pots receiving K_1P_1S and K_1P_1BMnS treatments. The analysis of variance, Table 10, indicated there was no significant difference in nitrogen content due to fertilizer treatments. The second cutting produced hay significantly higher in nitrogen than did the first or third cuttings. It is possible this could have been affected by serious infestations of insects prior to these two cuttings.

Results of phosphorus determinations are presented in Table 11. Analysis of variance and Multiple Range test are shown in Table 12. Plants containing the lowest percentage phosphorus, .0945 percent, were grown on pots receiving the K_1BMnS treatment, and the highest percentage, .1583 percent, was obtained from P_1 B and P_1 S treatments. The analysis of variance indicated differences, significant at the 1 percent level, due to fertility treatments, and highly significant differences due to cuttings. The K_1P_1Mn treatment was similar to the S treatment but significantly higher in phosphorus content than all other treatments not receiving the P_1 treatment. The

Table 7. Effect of various soil fertility treatments on yield of alfalfa hay from three cuttings in the greenhouse experiment, Port loam, 1956.*

Treatments**	3/12				4/7				5/12			
				Average				Average				Average
Check	15.6	13.7	13.8	14.37	9.2	6.7	6.2	7.37	7.5	6.5	7.7	7.23
B	11.3	12.8	14.0	12.70	7.2	7.7	5.3	6.73	7.1	8.5	5.9	7.17
Mn	13.2	15.9	15.4	14.83	7.2	8.7	7.8	7.90	7.3	8.6	7.2	7.70
S	14.2	12.2	18.7	15.03	6.9	6.7	8.3	7.30	6.9	7.0	8.8	7.57
BMnS	13.2	12.4	15.8	13.80	6.3	7.1	7.1	6.83	7.6	7.2	8.6	7.80
K_1	11.7	13.9	18.9	14.83	7.7	8.5	8.9	8.37	7.9	7.9	8.2	8.00
K_1B	13.1	12.6	17.1	14.27	7.9	6.7	8.4	7.67	7.1	6.6	8.0	7.23
K_1Mn	11.2	10.4	12.3	11.30	8.3	6.7	6.7	7.23	7.6	7.0	7.8	7.47
K_1S	14.0	15.4	14.2	14.53	9.3	7.9	8.8	8.67	8.3	8.4	6.8	7.83
K_1BMnS	12.0	12.9	15.1	13.33	7.1	8.0	8.3	7.80	8.5	7.4	7.6	7.83
P_1	16.2	15.3	17.2	16.23	8.4	7.0	8.1	7.83	6.7	7.7	8.6	7.67
P_1B	11.6	12.4	12.3	12.10	7.6	7.9	7.3	7.60	6.9	8.5	4.8	6.73
P_1Mn	14.3	15.2	15.0	14.50	8.6	7.3	8.0	7.97	7.2	7.1	8.1	7.47
P_1S	14.6	13.9	16.6	15.03	8.0	7.3	7.7	7.67	8.3	7.1	6.5	7.30
P_1BMnS	13.7	13.0	15.3	14.00	8.8	8.1	8.6	8.50	7.9	9.3	7.6	8.27
K_1P_1	15.1	13.7	17.9	15.57	11.5	8.6	8.8	9.63	10.1	8.0	8.6	8.90
K_1P_1B	14.6	14.1	18.4	15.70	8.7	8.4	8.5	8.53	8.5	8.7	7.3	8.17
K_1P_1Mn	13.0	16.0	16.7	15.23	8.2	8.3	8.9	8.47	8.0	7.9	11.1	9.00
K_1P_1S	16.9	14.0	12.6	14.50	9.0	8.8	6.9	8.23	7.8	8.5	6.3	7.53
K_1P_1BMnS	16.6	12.6	17.4	15.53	9.6	6.8	7.7	8.03	9.7	6.8	7.8	8.10

Cutting Dates: 3/12, 4/7, 5/12.

* Yields are in grams dry weight.
** See Table 23 for details of soil fertility treatments.

Table 8. Summary of analysis of variance, coefficient of variation, standard error of treatment mean and Multiple Range test for alfalfa hay yields, greenhouse experiment, Port loam.

Source	df	SS	MS	F
		Analysis of Variance		
Total	179	2071.40		
Treatments	19	84.59	4.452	2.574**
Cuttings	2	1720.94	860.47	497.5**
Replications	2	16.30	8.15	4.712*
Trt. X cuttings	38	45.48	1.197	0.692
Error	118	204.09	1.7296	

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

Coefficient of variation = 13.12%

Standard error of treatment mean = .43838

Multiple Range test

Treatment means ranked in order of magnitude.

K Mn	P_1 B	B	BMnS	Check	K_1 BMnS	K_1 B	S	P_1 S	P_1 Mn	K_1P_1 S	Mn	P_1 BMnS	K_1 S	K_1	K_1P_1 BMnS	P_1	K_1P_1 B	K_1P_1 Mn	K_1P_1
8.67	8.81	8.87	9.48	9.66	9.66	9.72	9.97	10.00	10.09	10.09	10.14	10.26	10.34	10.40	10.56	10.57	10.80	10.90	11.37

Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

Multiple Range test indicated K_1 treatment had a depressing effect, although not significant at the 1 percent level, on phosphorus content of plants not receiving the P_1 treatment but did not effect the phosphorus content of plants receiving phosphorus in the treatment. Application of phosphorus had the greatest influence, of the fertility treatments, on the uptake of phosphorus by the plant, in accordance with results obtained by Dennis and Chesnin (10).

Potassium content of the plant materials was determined and results are presented in Table 13. Analysis of variance, coefficient of variation and Multiple Range test are shown in Table 14. The lowest content of potassium, 1.89 percent, was obtained from plants receiving P_1Mn treatment. The highest content, 3.55 percent potassium, was obtained on pots receiving K BMnS treatment. The analysis of variance showed a significant difference in potassium content of plants, at the 1 percent level, due to treatments and also due to cuttings. The coefficient of variation was 7.84 percent. There was a difference, significant at the 1 percent level, in the potassium content of plants due to the potassium treatment. There was no significant difference between treatments receiving potassium. The potassium content of plants receiving the P_1Mn treatment was significantly lower than that of the plants receiving the following treatments: Check (no fertilizer), B, and Mn, but were similar to all others not receiving potassium. The Multiple Range test indicated phosphorus applications tended to reduce the uptake of potassium by the plants grown in pots not receiving potassium, although this difference was not significant at the 1 percent level.

Waynesboro loam. Analyses of this soil, shown in Table 1, indicated it was low in available phosphorus and organic matter. Exchangable potassium content of this soil was adequate for alfalfa production, according

Table 9. Effect of various soil fertility treatments on the percent nitrogen content of three successive cuttings of alfalfa hay in the greenhouse experiment, Port loam, 1956.*

Treatment	Date of Cutting 3/12	4/7	5/12	Average
Check	3.44	3.78	3.50	3.57
B	3.68	3.80	3.40	3.63
Mn	3.36	3.88	3.14	3.46
S	3.24	3.74	3.30	3.43
BMnS	3.50	3.77	3.14	3.47
K_1	3.18	3.74	3.34	3.42
K_1B	3.14	3.68	3.32	3.38
K_1Mn	3.17	3.70	3.14	3.34
K_1S	3.48	3.74	3.12	3.45
K_1BMnS	3.18	3.58	3.26	3.34
P_1	3.04	3.80	3.52	3.45
P_1B	3.76	4.04	3.36	3.72
P_1Mn	3.40	4.04	3.40	3.61
P_1S	3.70	3.64	3.32	3.55
P_1BMnS	3.72	3.48	3.34	3.51
K_1P_1	3.34	3.52	3.28	3.51
K_1P_1B	3.26	3.89	3.60	3.58
K_1P_1Mn	3.38	3.48	3.34	3.40
K_1P_1S	3.22	3.50	3.26	3.33
K_1P_1BMnS	3.36	3.44	3.18	3.33

* Each figure represents the mean of duplicate analyses on forage samples obtained by combining plant materials from three replicate pots receiving the same fertility treatments. See Table 23 for details of soil fertility treatment.

Table 10. Summary of analysis of variance, coefficient of variation, and standard error of treatment mean for nitrogen content of alfalfa hay, greenhouse experiment, Port loam

Source	df	SS	MS	F
Total	59	3.6265		
Treatments	19	.7248	.03815	1.353
Cuttings	2	1.8302	.9151	32.45**
Error	38	1.0715	.0282	

** Significant at the 1% level.

Coefficient of variation = 16.79%

Standard error of treatment mean = .097

Table 11. Effect of various soil fertility treatments on the percent phosphorus content of three successive cuttings of alfalfa hay in the greenhouse experiment, Port loam, 1956.*

Treatment	Date of Cutting 3/12	4/7	5/12	Average
Check	.0935	.1290	.1115	.1113
B	.0995	.1520	.1250	.1255
Mn	.1070	.1455	.1250	.1258
S	.1100	.1500	.1290	.1297
BMnS	.1070	.1420	.1160	.1217
K_1	.0965	.1250	.1100	.1105
K_1B	.0965	.1315	.0995	.1092
K_1Mn	.0995	.1190	.1010	.1065
K_1S	.1040	.1290	.1085	.1138
K_1BMnS	.0845	.1010	.0980	.0945
P_1	.1350	.1795	.1530	.1558
P_1B	.1500	.1710	.1540	.1583
P_1Mn	.1205	.1680	.1580	.1488
P_1S	.1410	.1780	.1560	.1583
P_1BMnS	.1430	.1780	.1480	.1563
K_1P	.1520	.1680	.1420	.1540
K_1P_1B	.1410	.1625	.1380	.1472
K_1P_1Mn	.1250	.1680	.1395	.1442
K_1P_1S	.1395	.1680	.1350	.1475
K_1P_1BMnS	.1395	.1625	.1420	.1480

* Each figure represents the mean of duplicate analyses of forage samples obtained by combining plant materials grown in the three replicate pots receiving the same fertility treatments. See Table 23 for details of soil fertility treatments.

Table 12. Summary of analysis of variance, coefficient of variation, standard error of the mean and Multiple Range test for phosphorus content of alfalfa hay in the greenhouse experiment, Port loam

		Analysis of Variance		
Source	df	SS	MS	F
Total	59	.03708		
Treatments	19	.02443	.001286	26.41**
Cuttings	2	.01080	.00540	110.93**
Error	38	.00185	.000049	

** Significant at the 1% level.

Coefficient of variation = 5.23%

Standard error of treatment mean = .00402

Multiple Range test

Treatment means ranked in order of magnitude.

K_1 BMnS	K_1 Mn	K_1 B	K_1	Check	K_1 S	BMnS	B	Mn	S	K_1P_1 Mn	K_1P_1 B	K_1P_1 S	K_1P_1 BMnS	P_1 Mn	K_1P_1	P_1	P_1 BMnS	P_1 B	P_1 S
.0945	.1065	.1092	.1105	.1113	.1138	.1217	.1255	.1258	.1297	.1442	.1472	.1475	.1480	.1488	.1540	.1558	.1563	.1583	.1583

Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

Table 13. Effect of various soil fertility treatments on the percent potassium content of three successive cuttings of alfalfa hay in the greenhouse experiment, Port loam, 1956.*

Treatment	Date of Cutting 3/12	4/7	5/12	Average
Check	2.29	2.90	2.16	2.45
B	2.70	2.87	2.12	2.56
Mn	2.32	2.92	2.46	2.57
S	2.25	2.67	1.95	2.29
BMnS	3.32	3.57	2.77	3.22
K_1	3.10	3.76	3.17	3.34
K_1B	3.17	3.29	3.37	3.49
K_1Mn	2.94	3.44	3.29	3.22
K_1S	3.19	3.70	3.37	3.42
K_1BMnS	3.42	3.81	3.42	3.55
P_1	2.60	2.27	1.63	2.17
P_1B	2.60	2.37	1.93	2.30
P_1Mn	2.04	1.92	1.71	1.89
P_1S	2.23	2.20	1.70	2.04
P_1BMnS	2.48	2.46	1.60	2.18
K_1P_1	3.00	3.27	3.00	3.09
K_1P_1B	3.37	3.60	3.27	3.41
K_1P_1Mn	3.15	3.89	3.32	3.45
K_1P_1S	3.12	3.47	3.05	3.21
K_1P_1BMnS	3.17	3.80	3.20	3.39

* Each figure represents the mean of duplicate analyses on forage samples obtained by combining plant materials from three replicate pots receiving the same fertility treatment. See Table 23 for details of soil fertility treatments.

Table 14. Summary of analysis of variance, coefficient of variation, standard error of treatment mean and Multiple Range test for potassium content of alfalfa hay, greenhouse experiment, Port loam

Source	df	Analysis of Variance SS	MS	F
Total	59	22.6267		
Treatments	19	18.3526	.9659	19.318**
Cuttings	2	2.3678	1.1839	23.678**
Error	38	1.9063	.05	

** Significant at the 1% P level.

Coefficient of variation = 7.84%

Standard error of treatment mean = .1292

Multiple Range test

Treatment means ranked in order of magnitude.

P_1 Mn	P_1 S	P_1	P_1 BMnS	S	P_1 B	Check	B	Mn	K_1P_1	K_1P_1 S	BMnS	K_1 Mn	K_1	K_1P_1 BMnS	K_1P_1 B	K_1 S	K_1P_1 Mn	K_1 B	K_1 BMnS
1.89	2.04	2.17	2.18	2.29	2.30	2.45	2.56	2.57	3.09	3.21	3.22	3.22	3.34	3.39	3.41	3.42	3.45	3.49	3.55
	———	———	———	———	———	———	———	———	———	———	———	———	———	———	———	———	———	———	———
———	———	———	———	———	———														

Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

to a critical level of this element proposed by Chandler, et al. (8). The reaction indicated a pH favorable for alfalfa production as explained by Schmehl, et al. (42) and Bear (3).

Three cuttings of alfalfa were harvested from this soil in the greenhouse experiment. Yields are presented in Tables 15, 30, 31 and 32. Analysis of variance and Multiple Range test are shown in Table 16. The lowest average yield, 7.50 grams, was obtained from pots receiving BMnS treatment and the highest average yield, 11.11 grams. was obtained from pots reveiving K_1P_1S treatment. The treatments containing boron proved to be toxic as indicated by yields and toxicity symptoms. The analysis of variance indicated a difference, at the 1 percent level, in yields due to fertility treatments. Yield from the K_1P_1S treated pots was significantly higher than yields from all boron treated pots and also the pots receiving check (no treatment), and Mn treatments. Yield from the Mn treatment, 9.28 grams, was significantly higher than the yields from BMnS and B treatments, and significantly lower than the yield from K_1P_1S treated pots but was similar to all other yields, obtained from this soil, in the greenhouse experiment. The yield from the pots receiving the check (no treatment) was significantly lower than the yield from K_1P_1S treated pots but was similar to the yield from other treatments on this soil.

Results from the chemical determinations for nitrogen, phosphorus and potassium contents of plants grown on this soil are presented in Tables 17, 19 and 21 respectively.

Analysis of variance, Table 18, indicated there was no difference between nitrogen contents of the forage due to fertility treatments. Highest percentage nitrogen content, 3.65 percent, was obtained from alfalfa receiving the B treatment. Lowest percentage nitrogen content, 3.18 percent,

Table 15. Effect of various soil fertility treatments on yield of alfalfa hay from three cuttings in the greenhouse experiment, Waynesboro loam, 1956.*

Treatments**	Cutting Dates 3/12				4/7				5/12			
				Average				Average				Average
Check	13.1	11.7	14.6	13.13	7.5	6.3	7.7	7.17	6.8	7.3	7.1	7.07
B	10.5	9.2	12.3	10.67	6.0	5.1	7.2	6.10	6.4	6.0	6.0	6.13
Mn	14.3	11.3	15.2	13.60	6.1	7.3	8.3	7.23	6.4	7.1	7.5	7.00
S	13.3	14.5	15.9	14.57	7.9	7.5	7.7	7.70	6.8	6.9	5.9	6.53
BMnS	9.2	9.6	11.2	10.00	5.3	5.7	7.6	6.20	5.6	6.5	6.8	6.30
K_1	11.6	12.8	16.1	13.50	8.6	7.5	9.7	8.60	7.7	7.2	7.9	7.60
K_1B	9.4	14.3	10.6	11.43	8.5	8.3	7.1	7.97	7.4	8.7	7.0	7.70
K_1Mn	13.6	14.2	13.7	13.83	9.8	8.3	9.2	9.10	8.8	7.6	7.6	8.00
K_1S	10.9	13.1	13.7	12.57	7.8	8.7	7.6	8.03	8.9	9.2	7.5	8.53
K_1BMnS	11.2	13.1	10.9	11.73	7.9	6.8	9.3	8.00	7.4	7.1	7.0	7.17
P_1	13.5	16.7	16.5	15.57	7.7	7.2	9.1	8.00	6.2	7.0	7.2	6.80
P_1B	13.1	6.8	12.9	10.97	7.4	4.7	7.6	6.57	7.1	5.1	6.3	6.17
P_1Mn	14.1	13.2	17.5	14.93	6.7	8.0	9.1	7.93	7.2	8.5	6.3	7.33
P_1S	13.5	14.5	15.0	14.33	7.5	7.3	8.9	7.90	6.8	8.1	6.5	7.13
P_1BMnS	12.3	13.7	11.0	12.33	6.6	3.6	6.7	5.63	6.4	5.4	4.9	5.57
K_1P_1	13.0	11.1	16.0	13.33	9.1	7.6	10.2	8.97	9.4	8.2	8.2	8.60
K_1P_1B	11.7	11.3	13.3	12.10	7.0	5.7	7.1	6.60	8.7	7.2	7.2	7.70
K_1P_1Mn	14.8	11.5	15.2	13.83	8.0	7.0	9.2	8.07	8.3	7.5	7.0	7.60
K_1P_1S	14.0	15.9	15.4	15.10	10.0	10.2	9.7	9.97	7.7	8.7	8.4	8.27
K_1P_1BMnS	12.0	12.3	13.7	12.60	8.6	6.7	8.4	7.90	6.4	7.5	6.3	6.73

* Yields are in grams dry weight.
** See Table 23 for details of soil fertility treatments.

Table 16. Summary of analysis of variance, coefficient of variation, standard error of treatment mean and Multiple Range test for alfalfa hay yields, greenhouse experiment, Waynesboro loam.

Source	df	SS	MS	F
		Analysis of Variance		
Total	179	1681.69		
Treatments	19	165.27	8.698	6.06**
Cuttings	2	1248.42	624.21	445.7**
Replications	2	22.21	11.105	7.738**
Trt. X Cuttings	38	76.48	2.013	1.403
Error	118	169.31	1.435	

** Significant at the 1% level.

Coefficient of variation = 12.91%

Standard error of treatment mean = .3993

Multiple Range test

Treatment means ranked in order of magnitude.

BMnS	B	P_1 BMnS	P_1 B	K_1P_1 B	K_1 BMnS	K_1 B	K_1P_1 BMnS	Check	Mn	S	K_1 S	P_1 S	K_1P_1 Mn	K_1	P_1 Mn	P_1	K_1P_1	K_1 Mn	K_1P_1 S
7.50	7.63	7.84	7.89	8.80	8.97	9.03	9.10	9.12	9.28	9.60	9.71	9.79	9.83	9.90	10.07	10.12	10.31	10.31	11.11

Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

was obtained from plants receiving the K_1P_1S treatment. This is not in agreement with results obtained by other workers (10) concerning the influence of phosphorus on the uptake of nitrogen by alfalfa.

Results from phosphorus determinations of alfalfa grown on the Waynesboro loam in the greenhouse experiment are shown in Table 19. Analysis of variance, coefficient of variation and Multiple Range test are shown in Table 20. The plant materials containing the lowest percentage phosphorus, .0910 percent, received the K_1BMnS treatment and the highest percentage phosphorus, .1320 percent, was contained in plants receiving P_1B treatment. This agrees with results obtained from Port loam soil in the experiment. Analysis of variance indicated differences, significant at the 1 percent level, in phosphorus content of the forage due to treatments and cuttings. Difference due to cuttings may be explained by heavy infestations of insects before the first cutting and prior to the third cutting. Potassium combined with the various trace element treatments reduced the phosphorus content in the plants. The Multiple Range test indicated potassium alone and with phosphorus treatments depressed phosphorus content although this was not significant. Application of phosphorus exerted the greatest influence on the content of this element in alfalfa in accordance with results obtained by Hunter (22).

Results of potassium determination on alfalfa grown on Waynesboro loam in the greenhouse are presented in Table 21. Analysis of variance, coefficient of variation and Multiple Range test are shown in Table 22. Analysis of variance indicated a significant difference, at the 1 percent level, in the potassium content of the plants due to soil fertility treatments. The lowest average content of potassium, 1.38 percent, was obtained on the P_1 treated pots. Highest average percentage potassium, 3.47 percent,

Table 17. Effect of various soil fertility treatments on the percent nitrogen content of three successive cuttings of alfalfa hay in the greenhouse experiment, Waynesboro loam, 1956.*

Treatment	Date of Cutting 3/12	4/7	5/12	Average
Check	3.01	3.52	3.50	3.34
B	3.36	4.08	3.52	3.65
Mn	3.40	3.90	3.58	
S	3.09	3.64	3.52	3.42
BMnS	3.10	3.80	3.52	3.47
K_1	3.22	3.50	3.28	3.33
K_1B	2.86	3.54	3.40	3.27
K_1Mn	3.28	3.74	3.24	
K_1S	3.08	3.66	3.36	3.37
K_1BMnS	3.14	3.22	3.30	3.22
P_1	3.20			3.51
P_1B	3.58	3.80	3.44	
P_1Mn	3.14		3.36	3.44
P_1S	3.23			3.46
P_1BMnS				3.37
K_1P_1	3.32	3.38	3.12	
K_1P_1B		3.56	3.24	3.35
K_1P_1Mn	3.50	3.15	3.06	3.24
K_1P_1S	3.07	3.45		3.18
K_1P_1BMnS	3.04	3.78	3.00	3.27

* Each figure represents the mean of duplicate analyses on forage samples obtained by combining plant materials from three replicate pots receiving the same fertility treatment. See Table 23 for details of soil fertility treatment.

Table 18. Summary of analysis of variance, coefficient of variation, and standard error of treatment mean for nitrogen content of alfalfa hay, greenhouse experiment, Waynesboro loam

Source	df	SS	MS	F
Total	59	5.8407		
Treatments	19	1.0927	.0575	0.94
Cuttings	2	2.4350	1.2175	19.9**
Error	38	2.3130	.0609	

** Significant at the 1% level.

Coefficient of variation = 7.29%

Standard error of treatment mean = .1424

Table 19. Effect of various soil fertility treatments on the percent phosphorus content of three successive cuttings of alfalfa hay in the greenhouse experiment, Waynesboro loam, 1956.*

Treatment	Date of Cutting 3/12	4/7	5/12	Average
Check	.0905	.1235	.1145	.1095
B	.0830	.1290	.0950	.1023
Mn	.0845	.1235	.1100	.1060
S	.0800	.1320	.1040	.1053
BMnS	.0815	.1190	.0995	.1000
K_1	.0970	.1070	.0950	.0997
K_1B	.0830	.1055	.0875	.0920
K_1Mn	.0920	.1070	.0935	.0975
K_1S	.0950	.1100	.0900	.0983
K_1BMnS	.0890	.1010	.0830	.0910
P_1	.1040	.1500	.1320	.1287
P_1B	.1160	.1510	.1290	.1320
P_1Mn	.1115	.1480	.1305	.1300
P_1S	.1100	.1395	.1290	.1262
P_1BMnS	.1070	.1360	.1190	.1207
K_1P_1	.1010	.1190	.1010	.1070
K_1P_1B	.1070	.1250	.1160	.1160
K_1P_1Mn	.1010	.1205	.0965	.1060
K_1P_1S	.0890	.1190	.0950	.1010
K_1P_1BMnS	.0875	.1070	.0935	.0960

* Each figure represents the mean of duplicate analyses of forage samples obtained by combining plant materials grown in three replicate pots receiving the same fertility treatments. See Table 23 for details of soil fertility treatments.

Table 20. Summary of analysis of variance, coefficient of variation, standard error of treatment mean and Multiple Range test for phosphorus content of alfalfa hay, greenhouse experiment, Waynesboro loam

Source	df	Analysis of Variance SS	MS	F
Total	59	.01961		
Treatments	19	.00952	.000501	9.824**
Cuttings	2	.00815	.004075	79.90**
Error	38	.00194	.000051	

** Significant at the 1% level.

Coefficient of variation = 6.59%

Standard error of treatment mean = .00412

Multiple Range test

Treatment means ranked in order of magnitude.

K_1 BMnS	K_1 B	K_1P_1 BMnS	K_1 Mn	K_1 S	K_1	BMnS	K_1P_1 S	B	S	Mn	K_1P_1 Mn	K_1P_1	Check	K_1P_1 B	P_1 BMnS	P_1 S	P_1	P_1 Mn	P_1 B
.0910	.0920	.0960	.0975	.0983	.0997	.1000	.1010	.1023	.1053	.1060	.1060	.1070	.1095	.1160	.1207	.1262	.1287	.1300	.1320
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Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

was obtained from plants receiving the K_1P_1B treatment. The Multiple Range test shows a significant difference in content of potassium in plants between treatments containing K_1 and those receiving no potassium in the treatment. There was no significant difference in potassium content of forage produced on pots receiving no potassium in the treatments. Addition of potassium was the only factor which significantly influenced the uptake of this element by alfalfa grown on this soil.

The means of three replications from three cuttings on both soils are presented in Table 23. Analysis of variance and Multiple Range test for the two soils combined are presented in Table 24. The analysis of variance indicated differences, at the 1 percent level, in yield, due to treatments, soils, and the interaction (treatments X soils). Yields from the Port loam were significantly higher than yields from Waynesboro loam. The lowest mean yield of the two soils combined, was obtained from the pots receiving B treatment and the highest mean yield was obtained from the pots receiving K_1P_1 treatment.

Table 21. Effect of various soil fertility treatments on the percent potassium content of three successive cuttings of alfalfa hay in the greenhouse experiment, Waynesboro loam, 1956.*

Treatment	Date of Cutting 3/12	4/7	5/12	Average
Check	1.79	2.04	1.17	1.67
B	2.01	2.23	1.06	1.77
Mn	1.59	1.74	1.10	1.48
S	1.65	1.95	1.00	1.53
BMnS	2.14	2.08	1.17	1.80
K_1	2.79	3.84	3.24	3.29
K_1B	3.04	3.98	3.25	3.42
K_1Mn	2.97	3.98	3.07	3.34
K_1S	3.14	3.85	3.08	3.36
K_1BMnS	3.12	3.88	3.09	3.36
P_1	1.46	1.64	1.04	1.38
P_1B	1.61	1.97	1.15	1.58
P_1Mn	1.54	1.82	0.92	1.43
P_1S	1.42	1.76	1.06	1.45
P_1BMnS	1.44	1.98	1.18	1.53
K_1P_1	2.65	3.73	3.01	3.13
K_1P_1B	3.30	4.12	2.99	3.47
K_1P_1Mn	2.61	3.84	2.97	3.14
K_1P_1S	2.91	3.81	3.00	3.24
K_1P_1BMnS	2.57	3.73	3.14	3.15

* Each figure represents the mean of duplicate analyses on forage samples obtained by combining plant materials from three replicate pots receiving the same fertility treatments. See Table 23 for details of soil fertility treatments.

Table 22. Summary of analysis of variance, coefficient of variation, standard error of treatment mean, and Multiple Range test for potassium content of alfalfa hay, greenhouse experiment, Waynesboro loam

Source of Variation	df	Analysis of Variance SS	MS	F
Total	59	55.6920		
Treatments	19	46.0213	2.4222	36.98**
Cuttings	2	7.1808	3.5904	54.81**
Error	38	2.4899	.0655	

** Significant at the 1% level.

Coefficient of variation 10.52%

Standard error of treatment mean = .1477

Multiple Range test

Treatment means ranked in order of magnitude.

P_1	P_1 Mn	P_1 S	Mn	P_1 BMnS	S-	P_1 B	Check	B	BMnS	K_1P_1	K_1P_1 Mn	K_1P_1 BMnS	K_1P_1 S	K_1	K_1 Mn	K_1 S	K_1 BMnS	K_1 B	K_1P_1 B
1.38	1.43	1.45	1.48	1.53	1.53	1.58	1.67	1.77	1.80	3.13	3.14	3.15	3.24	3.29	3.34	3.36	3.36	3.42	3.47

Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

Table 23. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Port loam and Waynesboro loam, 1956.*

	Port loam				Waynesboro loam			
	Date of cutting				Date of cutting			
Treatment**	3/12	4/7	5/12	Total	3/12	4/7	5/12	Total
Check	14.37	7.37	7.23	28.97	13.13	7.17	7.07	27.37
B	12.70	6.73	7.17	26.60	10.67	6.10	6.13	22.90
Mn	14.83	7.90	7.70	30.43	13.60	7.23	7.00	27.83
S	15.03	7.30	7.57	29.90	14.57	7.70	6.53	28.80
BMnS	13.80	6.83	7.80	28.43	10.00	6.20	6.30	22.50
K_1	14.83	8.37	8.00	31.20	13.50	8.60	7.60	29.70
K_1B	14.27	7.67	7.23	29.17	11.43	7.97	7.70	27.10
K_1Mn	11.30	7.23	7.47	26.00	13.83	9.10	8.00	30.93
K_1S	14.53	8.67	7.83	31.03	12.57	8.03	8.53	29.13
K_1BMnS	13.33	7.80	7.83	28.96	11.73	8.00	7.17	26.90
P_1	16.23	7.83	7.67	31.73	15.57	8.00	6.80	30.37
P_1B	12.10	7.60	6.73	26.43	10.97	6.57	6.17	23.71
P_1Mn	14.50	7.97	7.47	29.94	14.93	7.93	7.33	30.19
P_1S	15.03	7.67	7.30	30.00	14.33	7.90	7.13	29.36
P_1BMnS	14.00	8.50	8.27	30.77	12.33	5.63	5.57	23.53
K_1P_1	15.57	9.63	8.90	34.10	13.33	8.97	8.60	30.90
K_1P_1B	15.70	8.53	8.17	32.40	12.10	6.60	7.70	26.40
K_1P_1Mn	15.23	8.47	9.00	32.70	13.83	8.07	7.60	29.50
K_1P_1S	14.50	8.23	7.53	30.26	15.10	9.97	8.27	33.34
K_1P_1BMnS	15.53	8.03	8.10	31.66	12.60	7.90	6.73	27.23

* Each figure represents in grams, the mean of three replicate pots each receiving the same fertility treatment.

** Treatment symbols are as follows:

Check = no fertilizer
B = 50 pounds boron/acre as Boric Acid C.P.
Mn = 50 pounds manganese/acre as Manganese Sulfate C.P.
S = 100 pounds sulfur/acre as Flowers of Sulfur
K_1 = 200 pounds K_2O/acre as Potassium Chloride C.P.
P_1 = 400 pounds P_2O_5/acre as Mono-Calcium Phosphate C.P.

Table 24. Summary of analysis of variance, coefficient of variation, standard error of treatment mean and Multiple Range test for alfalfa hay yields, greenhouse experiment, Port loam and Waynesboro loam.

Analysis of Variance				
Source	df	SS	MS	F
Total	359	3799.88		
Treatments	19	145.07	7.635	4.77**
Soils	1	18.14	18.14	11.34**
Cuttings	2	2946.71	1473.355	920.85**
Trt. X Soils	19	136.92	7.206	4.50**
Trt. X cuttings	38	116.58	3.068	1.92**
Error	280	436.46	1.6	

** Significant at the 1% level.

Coefficient of variation = 13.07%

Standard error of treatment mean = .2981

Multiple Range test

Treatment means ranked in order of magnitude.

B	P_1 B	BMnS	P_1 BMnS	K_1 BMnS	K_1 B	Check	K_1 Mn	Mn	S	K_1P_1 B	K_1P_1 BMnS	P_1 S	K_1 S	P_1 Mn	K_1	P_1	K_1P_1 Mn	K_1P_1 S	K_1P_1
8.25	8.35	8.49	9.05	9.31	9.38	9.39	9.49	9.71	9.78	9.80	9.83	9.89	10.03	10.08	10.15	10.35	10.37	10.60	10.84
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Any two means not underscored by the same line are significantly different at the 1% probability level.
Any two means underscored by the same line are not significantly different at the 1% probability level.

VI SUMMARY AND CONCLUSIONS

The objective of this study was to determine effects of various soil fertility treatments on yield and compostion of alfalfa grown on two contrasting soil types. Field experiments were conducted at two locations, one near Stillwater, Oklahoma, on Port loam, and one at the Southeastern Oklahoma Soil Improvement Station on Waynesboro loam. Greenhouse studies with these two soils were conducted at Stillwater.

Fertility treatments used in this study included different rates of phosphorus and potassium fertilizers and applications of various trace elements including boron, manganese and sulfur. Magnesium was included as a variable in the field experiment on Waynesboro loam and manganese was not included as a treatment in that experiment.

Three alfalfa hay cuttings from each of the field experiments were obtained in 1955. Three cuttings were obtained from the greenhouse experiment in 1956.

Results from the field experiments may be summarized as follows:

1. There was a significant linear response to the three rates of phosphorus fertilizer on Port loam.
2. A quadratic response to the three rates of potassium fertilization was indicated, on the Port loam, but was not significant at the 5 percent probability level.
3. There was no significant interaction between the various fertility treatments including boron, on the Port loam soil.

4. Applications of potassium significantly increased yield of alfalfa hay on Waynesboro loam.
5. On Waynesboro loam there was no significant difference in yield affected by interaction of potassium and other fertilizer treatments.

Results from the greenhouse experiment may be summarized as follows:

1. The highest yields on Port loam were from pots receiving 200 pounds K_2O per acre as KCl and 400 pounds P_2O_5 per acre as $Ca(H_2PO_4)_2 \cdot H_2O$. This treatment plus 100 pounds sulfur (P_1K_1S) gave the highest yields on the Waynesboro loam.
2. Fifty pounds of boron per acre, applied as H_3BO_4, were apparently toxic on both soils.
3. Fertility treatments did not significantly influence nitrogen content of alfalfa grown on either of the soils.
4. Applications of phosphorus resulted in a significant increase in uptake of this element by alfalfa grown on both soils.
5. Plant material from pots receiving 200 pounds K_2O, 400 pounds P_2O_5 and 50 pounds Mn per acre, on Port loam, had a phosphorus content similar to plants from pots receiving 100 pounds sulfur per acre but significantly higher than all other plant material not receiving phosphorus fertilizer.
6. Potassium combined with the trace elements tended to reduce the phosphorus content of alfalfa on Waynesboro loam. Potassium did not effect phosphorus content of alfalfa receiving phosphorus in the treatment on the Port loam but tended to reduce the phosphorus content of plants not receiving phosphorus in the fertility treatment.

7. Applications of potassium resulted in a higher content of this element in alfalfa grown on both soils.

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APPENDIX

Figure 1. General view of the alfalfa fertility pot experiment in the greenhouse.

Figure 2. Growth of alfalfa at three weeks, as affected by soil; (A) Waynesboro loam, and (B) Port loam. Both pots received 400 lbs. P_2O_5, 50 lbs. boron, 50 lbs. manganese, and 100 lbs. sulfur per acre.

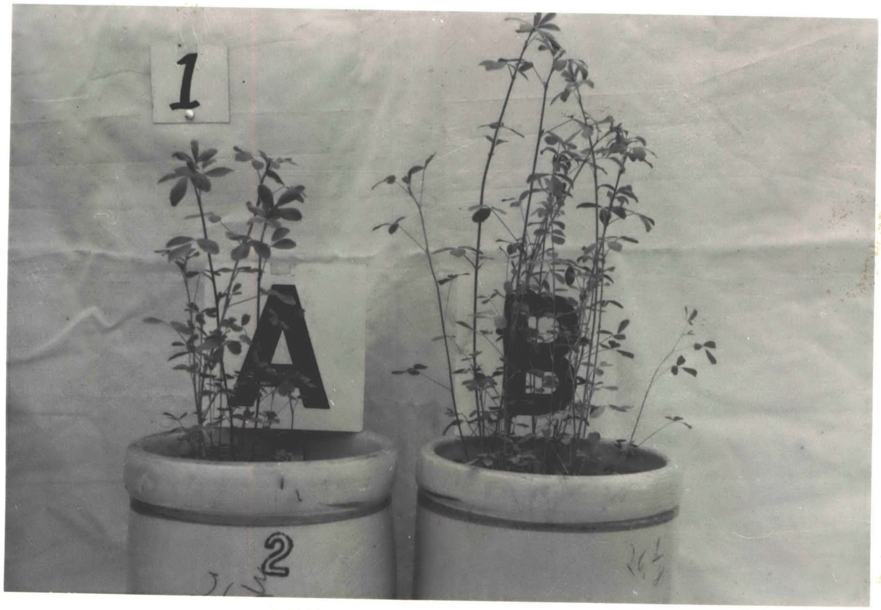

Figure 3. Growth of alfalfa on Waynesboro loam, at two weeks as affected by potassium treatment; (A) without potassium, (B) 200 lbs. K_2O/A. Both pots received 400 lbs. P_2O_5 and 50 lbs. B/A.

Figure 4. Growth of alfalfa on Waynesboro loam, at two weeks, as affected by phosphorus treatment; (A) without phosphours, (B) 400 lbs. P_2O_5/A. Both pots received 200 lbs. K_2O and 50 lbs. B/A.

Table 25 The effect of various soil fertility treatments on yield of alfalfa hay in the field experiment, Port loam, Thomas farm, Stillwater, Oklahoma, 1955.

	Pounds of hay per acre by replication at cutting date.								
	6/10			7/14			11/1		
Treatment*	1	2	3	1	2	3	1	2	3
Check	1999	2425	2042	1638	1595	1234	659	849	213
P_1	2169	2254	2212	1574	1701	1446	766	893	489
P_2	2765	2127	1999	1850	1978	1446	1021	681	808
K_1	2127	2382	2127	1701	1616	1655	723	553	191
P_1K_1	2339	2254	2212	1765	1616	1701	872	723	511
P_2K_1	2553	1914	2510	1914	1744	1872	1021	829	851
K_2	2339	2254	2169	1489	1531	1404	851	468	298
P_1K_2	2254	2339	2297	1744	1446	1489	829	681	489
P_2K_2	2127	2127	2382	1808	1872	1680	1021	829	829
B	2127	2467	1999	1786	1489	1510	723	638	553
P_1B	2339	1957	1914	1978	1574	1319	936	978	425
P_2B	2552	2339	2084	2042	1829	1361	1106	766	532
K_1B	2042	2084	2169	1786	1361	1659	915	425	340
P_1K_1B	2637	2339	2339	2169	1786	1489	1000	957	362
P_2K_1B	2425	2467	2169	1935	1999	1659	978	723	659
K_2B	2127	2084	2467	1680	1340	1489	872	404	298
P_1K_2B	2722	2510	2339	1893	1574	1574	851	872	404
P_2K_2B	2382	2084	2425	1829	1595	1829	936	595	723

* See Table 2 for details of soil fertility treatments.

Table 26. The effect of various soil fertility treatments on yield of alfalfa hay in the field experiment, Waynesboro loam, Heavener, Oklahoma, 1955.

	Pounds hay per acre by replication at cutting date.								
	6/28			8/31			10/25		
Treatment*	1	2	3	1	2	3	1	2	3
Check	548	444	178	652	652	385	30	89	0
K	607	948	578	800	933	474	652	489	341
P_1	578	888	74	489	874	237	133	400	00
P_1K	815	1422	237	830	1304	489	533	800	237
P_2	444	385	178	341	385	148	0	0	0
P_2K	963	622	148	1259	993	533	815	682	178
R_1	474	830	756	593	711	785	237	504	207
R_1K	919	1141	933	904	889	830	637	756	311
R_2	563	133	341	474	237	207	282	0	0
R_2K	888	1008	519	845	845	622	711	533	296
R_1P_1	222	400	533	430	444	578	119	0	163
R_1P_1K	637	800	1037	919	919	830	563	444	504
R_1P_1B	474	459	119	889	533	252	533	148	0
R_1P_1BK	1037	1037	430	1126	785	682	815	311	267
R_1P_1Mg	282	563	400	356	342	459	118	0	178
R_1P_1MgK	874	667	1170	1052	1126	933	770	652	652
R_1P_1S	1185	815	163	1067	593	297	637	0	0
R_1P_1SK	1111	1200	504	1274	1215	696	874	696	311
R_1P_1BMgS	1245	593	637	1141	519	563	592	133	178
R_1P_1BMgSK	1378	1067	1052	1259	845	741	696	355	370

* See Table 5 for details of soil fertility treatments.

Table 27. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Port loam, March 12, 1956.*

Treatment**	Replication I	II	III	Mean
Check	15.6	13.7	13.8	14.37
B	11.3	12.8	14.0	12.70
Mn	13.2	15.9	15.4	14.83
S	14.2	12.2	18.7	15.03
K_1	11.7	13.9	18.9	14.83
K_1B	13.1	12.6	17.1	14.27
K_1Mn	11.2	10.4	12.3	11.30
K_1S	14.0	15.4	14.2	14.53
K_1BMnS	12.0	12.9	15.1	13.33
P_1	16.2	15.3	17.2	16.23
P_1B	11.6	12.4	12.3	12.10
P_1Mn	14.3	15.2	15.0	14.50
P_1S	14.6	13.9	16.6	15.03
P_1BMnS	13.7	13.0	15.3	14.00
K_1P_1	15.1	13.7	17.9	15.57
K_1P_1B	14.6	14.1	18.4	15.70
K_1P_1Mn	13.0	16.0	16.7	15.23
K_1P_1S	16.9	14.0	12.6	14.50
K_1P_1BMnS	16.6	12.6	17.4	15.53

* Yields are in grams.
** See Table 23 for details of soil fertility treatments.

Table 28. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Port loam, April 7, 1956.*

Treatments**	Replication I	Replication II	Replication III	Mean
Check	9.2	6.7	6.2	7.37
B	7.2	7.7	5.3	6.73
Mn	7.2	8.7	7.8	7.90
S	6.9	6.7	8.3	7.30
BMnS	6.3	7.1	7.1	6.83
K_1	7.7	8.5	8.9	8.37
K_1B	7.9	6.7	8.4	7.67
K_1Mn	8.3	6.7	6.7	7.23
K_1S	9.3	7.9	8.8	8.67
K_1BMnS	7.1	8.0	8.3	7.80
P_1	8.4	7.0	8.1	7.83
P_1B	7.6	7.9	7.3	7.60
P_1Mn	8.6	7.3	8.0	7.97
P_1S	8.0	7.3	7.7	7.67
P_1BMnS	8.8	8.1	8.6	8.50
K_1P_1	11.5	8.6	8.8	9.63
K_1P_1B	8.7	8.4	8.5	8.53
K_1P_1Mn	8.2	8.3	8.9	8.47
K_1P_1S	9.0	8.8	6.9	8.23
K_1P_1BMnS	9.6	6.8	7.7	8.03

* Yields are in grams.
** See Table 23 for details of soil fertility treatments.

Table 29. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Port loam, May 12, 1956.*

Treatment**	Replication I	II	III	Mean
Check	7.5	6.5	7.7	7.23
B	7.1	8.5	5.9	7.17
Mn	7.3	8.6	7.2	7.70
S	6.9	7.0	8.8	7.57
BMnS	7.6	7.2	8.6	7.80
K_1	7.9	7.9	8.2	8.00
K_1B	7.1	6.6	8.0	7.23
K_1Mn	7.6	7.0	7.8	7.47
K_1S	8.3	8.4	6.8	7.83
K_1BMnS	8.5	7.4	7.6	7.83
P_1	6.7	7.7	8.6	7.67
P_1B	6.9	8.5	4.8	6.73
P_1Mn	7.2	7.1	8.1	7.47
P_1S	8.3	7.1	6.5	7.30
P_1BMnS	7.9	9.3	7.6	8.27
K_1P_1	10.1	8.0	8.6	8.90
K_1P_1B	8.5	8.7	7.3	8.17
K_1P_1Mn	8.0	7.9	11.1	9.00
K_1P_1S	7.8	8.5	6.3	7.53
K_1P_1BMnS	9.7	6.8	7.8	8.10

* Yields are in grams.
** See Table 23 for details of soil fertility treatments.

Table 30. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Waynesboro loam, March 12, 1956.*

Treatments**	Replication I	II	III	Mean
Check	13.1	11.7	14.6	13.13
B	10.5	9.2	12.3	10.67
Mn	14.3	11.3	15.2	13.60
S	13.3	14.5	15.9	14.57
BMnS	9.2	9.6	11.2	10.00
K_1	11.6	12.8	16.1	13.50
K_1B	9.4	14.3	10.6	11.43
K_1Mn	13.6	14.2	13.7	13.83
K_1S	10.9	13.1	13.7	12.57
K_1BMnS	11.2	13.1	10.9	11.73
P_1	13.5	16.7	16.5	15.57
P_1B	13.1	6.8	12.9	10.97
P_1Mn	14.1	13.2	17.5	14.93
P_1S	13.5	14.5	15.0	14.33
P_1BMnS	12.3	13.7	11.0	12.33
K_1P_1	13.0	11.1	16.0	13.33
K_1P_1B	11.7	11.3	13.3	12.10
K_1P_1Mn	14.8	11.5	15.2	13.83
K_1P_1S	14.0	15.9	15.4	15.10
K_1P_1BMnS	12.0	12.3	13.7	12.60

* Yields are in grams.
** See Table 23 for details of soil fertility treatments.

Table 31. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Waynesboro loam, April 7, 1956.*

Treatments**	Replication I	Replication II	Replication III	Mean
Check	7.5	6.3	7.7	7.17
B	6.0	5.1	7.2	6.10
Mn	6.1	7.3	8.3	7.23
S	7.9	7.5	7.7	7.70
BMnS	5.3	5.7	7.6	6.20
K_1	8.6	7.5	9.7	8.60
K_1B	8.5	8.3	7.1	7.97
K_1Mn	9.8	8.3	9.2	9.10
K_1S	7.8	8.7	7.6	8.03
K_1BMnS	7.9	6.8	9.3	8.00
P_1	7.7	7.2	9.1	8.00
P_1B	7.4	4.7	7.6	6.57
P_1Mn	6.7	8.0	9.1	7.93
P_1S	7.5	7.3	8.9	7.90
P_1BMnS	6.6	3.6	6.7	5.63
K_1P_1	9.1	7.6	10.2	8.97
K_1P_1B	7.0	5.7	7.1	6.60
K_1P_1Mn	8.0	7.0	9.2	8.07
K_1P_1S	10.0	10.2	9.7	9.97
K_1P_1BMnS	8.6	6.7	8.4	7.90

* Yields are in grams.
** See Table 23 for details of soil fertility treatments.

Table 32. Effect of various soil fertility treatments on yield of alfalfa hay in the greenhouse experiment, Waynesboro loam, May 12, 1956.*

	Replication			Mean
Treatments**	I	II	III	
Check	6.8	7.3	7.1	7.07
B	6.4	6.0	6.0	6.13
Mn	6.4	7.1	7.5	7.00
S	6.8	6.9	5.9	6.53
BMnS	5.6	6.5	6.8	6.30
K_1	7.7	7.2	7.9	7.60
K_1B	7.4	8.7	7.0	7.70
K_1Mn	8.8	7.6	7.6	8.00
K_1S	8.9	9.2	7.5	8.53
K_1BMnS	7.4	7.1	7.0	7.17
P_1	6.2	7.0	7.2	6.80
P_1B	7.1	5.1	6.3	6.17
P_1Mn	7.2	8.5	6.3	7.33
P_1S	6.8	8.1	6.5	7.13
P_1BMnS	6.4	5.4	4.9	5.57
K_1P_1	9.4	8.2	8.2	8.60
K_1P_1B	8.7	7.2	7.2	7.70
K_1P_1Mn	8.3	7.5	7.0	7.60
K_1P_1S	7.7	8.7	8.4	8.27
K_1P_1BMnS	6.4	7.5	6.3	6.73

* Yields are in grams.
** See Table 23 for details of soil fertility treatments.

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Master of Science

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