

May 28, 1959

To the Graduate Council:

I am submitting herewith a thesis written by Kenneth L. Wells entitled "Vertical Distribution of Soil Phosphorus and Potassium on Several Established Alfalfa Stands that Received Various Rates of Annual Fertilization." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

W. L. Parks
Major Professor

We have read this thesis and
recommend its acceptance:

M. E. Springer
Lawrence N. Sheld

Accepted for the Council:

Oak Mantling
Dean of the Graduate School

VERTICAL DISTRIBUTION OF SOIL PHOSPHORUS AND POTASSIUM ON SEVERAL
ESTABLISHED ALFALFA STANDS THAT RECEIVED VARIOUS
RATES OF ANNUAL FERTILIZATION

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Kenneth L. Wells

June 1959

28
33

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to:

Dr. W. L. Parks for his advice and encouragement throughout the period of graduate study.

Dr. M. E. Springer, Mr. L. N. Skold and other members of the Agronomy Department for their cooperation and helpful suggestions, and

The American Potash Institute for their financial support which made this study possible.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION.	1
II. REVIEW OF LITERATURE	2
III. METHODS AND PROCEDURES	8
IV. RESULTS.	11
Potassium Soil Test Results	11
Phosphorus Soil Test Results	16
Soil pH Level Data	20
Calcium and Magnesium Soil Test Data	25
Yield of Alfalfa Hay	25
Correlation of Soil Test Data and 1957 Yield Data.	31
V. DISCUSSION AND CONCLUSIONS	36
Potassium Soil Test Data	36
Phosphorus Soil Test Data	37
Soil pH Data	38
Calcium and Magnesium Soil Test Data	38
Yield Data	38
Correlation of Soil Test Values and Yield Results	39
VI. SUMMARY.	42
LITERATURE CITED	44
APPENDIXES.	47
Appendix A. Procedure for Determination of Exchangeable Calcium and Magnesium of Soils	48

CHAPTER

PAGE

APPENDIXES (continued)

Appendix B. Procedure for Determination of Available Phosphorus and Exchangeable Potassium in Soils	50
Appendix C. Procedure for Determination of pH of Soils	51
Appendix D. Soil Test Values for Exchangeable Cations, Available Phosphorus, and pH on Maury Silt Loam Following Various Annual Fertility Treatments.	52
Appendix E. Soil Test Values for Exchangeable Cations, Available Phosphorus, and pH on Decatur Silty Clay Loam Following Various Annual Fertility Treatments	54
Appendix F. Soil Test Values for Exchangeable Cations, Available Phosphorus, and pH on Dunmore Silt Loam Following Various Annual Fertility Treatments	59
Appendix G. Soil Test Values for Exchangeable Cations, Available Phosphorus, and pH on Dickson Silt Loam Following Various Annual Fertility Treatments	62
Appendix H. c_{ij} Values With Ex_{1y} and Resulting Partial Regression Coefficients Where $Y = f(K_{0-1}'' +$ $K_{1-3}'' + K_{3-6}'' + K_{6-12}'')$	66

APPENDIXES (continued)

Appendix I. c_{ij} Values With Ex_{1y} and Resulting Partial

Regression Coefficients Where $Y = f(K_{0-1''} +$

$K_{1-3''} + K_{3-6''} + K_{6-12''} + K_{12-18''} + K_{18-24''} +$

$K_{24-30''} + K_{30-36''}) \dots \dots \dots 67$

Appendix J. c_{ij} Values With Ex_{1y} and Resulting Partial

Regression Coefficients Where $Y = f(P_{0-6''} +$

$K_{0-6''} + P_{0-6''}^2 + K_{0-6''}^2 + PK_{0-6''})$

LIST OF TABLES

TABLE	PAGE
I. Average Yield of Alfalfa From Maury Silt Loam of the 5th and 6th Productive Years After Various Rates of Annual Topdressing	26
II. Average Yield of Alfalfa From Decatur Silty Clay Loam of 4th and 5th Productive Years After Various Rates of Annual Topdressing	27
III. Average Yield of Alfalfa From Dunmore Silt Loam of the 4th and 5th Productive Years After Various Rates of Annual Topdressing	28
IV. Average Yield of Alfalfa From Dickson Silt Loam of 4th and 5th Productive Years After Various Rates of Annual Topdressing	29
V. R^2 and r^2 Values Where $Y = f(K_{0-1''} + K_{1-3''} +$ $K_{3-6''} + K_{6-12''} + K_{12-18''} + K_{18-24''} + K_{24-30''} +$ $K_{30-36''})$	32
VI. R^2 Values Where $Y = f(P_{0-6''} + K_{0-6''} + P_{0-6''}^2 +$ $K_{0-6''}^2 + PK)$	35

LIST OF FIGURES

FIGURE	PAGE
1. Potassium Soil Test Values at Several Depths in Maury Silt Loam After Five Annual Topdressings of Potash at Five Rates.	12
2. Potassium Soil Test Values at Several Depths in Decatur Silty Clay Loam After Four Annual Topdressings of Potash at Five Rates	13
3. Potassium Soil Test Values at Several Depths in Dunmore Silt Loam After Four Annual Topdressings of Potash at Five Rates	14
4. Potassium Soil Test Values at Several Depths in Dickson Silt Loam After Four Annual Topdressings of Potash at Five Rates	15
5. Phosphorus Soil Test Values at Several Depths in Decatur Silty Clay Loam After Four Annual Top- dressings of Phosphate at Four Rates.	17
6. Phosphorus Soil Test Values at Several Depths in Dunmore Silt Loam After Four Annual Topdressings of Phosphate at Four Rates.	18
7. Phosphorus Soil Test Values at Several Depths in Dickson Silt Loam After Four Annual Topdressings of Phosphate at Four Rates	19
8. Soil pH Values at Several Depths in Maury Silt Loam After Five Annual Topdressings of Potash at Various Rates.	21

FIGURE

PAGE

9.	Soil pH Values at Several Depths in Decatur Silty Clay Loam After Four Annual Topdressings of Potash at Various Rates.	22
10.	Soil pH Values at Several Depths in Dunmore Silt Loam After Four Annual Topdressings of Potash at Various Rates.	23
11.	Soil pH Values at Several Depths in Dickson Silt Loam After Four Annual Topdressings of Potash at Various Rates.	24

CHAPTER I

INTRODUCTION

This investigation was designed to evaluate the effect of various rates of annual topdressings of fertilizer on soil test values for exchangeable cations, available phosphorus, and pH of the soil at various depths under established alfalfa stands on four soil types.

The yield of alfalfa hay from each soil was correlated with the soil test values of various layers for each location.



CHAPTER II

REVIEW OF LITERATURE

Literature relating to the soil and crop effects of potassium fertilization of alfalfa is quite extensive. However, literature concerning the effect of potassium fertilization of alfalfa on the distribution of available potassium throughout the soil profile is not quite so abundant.

The relationship between the composition of plants and the soils on which they were grown has been studied for more than 300 years (3). Around 1860, the German botanists, Knop and Sachs, did extensive investigations to determine specifically which elements were essential for plant growth. Their investigations, which were subsequently confirmed by other workers, indicated that potassium was one of the essential elements (4,16). Since potassium is an essential element, it is to be expected that there is a relationship existing between available soil potassium and the amount of potassium in the plant grown. Different plant species vary in their capacity to absorb potassium from the soil and also in the amount of potassium required for normal growth.

Alfalfa has a marked capacity to absorb a much larger quantity of potassium than is necessary for optimum growth (1,2,27). This is known as luxury consumption. Work done by Bear and Wallace (2) suggested that the critical level for potassium in alfalfa plants is 1.4 per cent. Stivers, et al. (23) found the critical level of potassium in the alfalfa plant for survival to be 0.9 to 1.1 per cent. Gerwig and Ahlgren (12) found this level to be between 1.42 and 1.84 per cent.

Some relationships have been found to exist between the soil fertility level of potassium and the potassium content of the alfalfa plant. As the soil potash level increased, a higher potassium content and lower magnesium and calcium contents were found in alfalfa (12). Vandecaveye and Bond (26) found in field experiments that the application of potassium fertilizers to alfalfa increased the potassium content of the crop. That potassium content of a normal alfalfa plant was doubled by adding more potassium fertilizer, was shown by the work of Woodhouse (27). Snider (22) found that the per cent of potassium in alfalfa was proportional to the available potassium in the soil, and tended to be higher in wet years. This agreed with the experiments of Seay, et al. (20) which showed that for closely related soils, the potassium content of the crop could be satisfactorily predicted when the content of exchangeable potassium in the soil on which the crop was grown was known.

In the comparison of yield and potassium content, Stivers, et al. (23) found that there was no consistent relationship between yield and the potassium content of the alfalfa crop. Experiments by Doll (8) on Tilsit silt loam showed a highly significant increase in yield of alfalfa hay for each increase in potassium fertilizer with treatments of 0, 33, 66, and 120 pounds of K_2O per acre respectively. The potassium content of the hay analyzed from each treatment was higher for each corresponding higher potassium fertilizer addition.

Seay and Weeks (21) found that potassium fertilization did not affect phosphorus uptake by alfalfa and that phosphorus fertilization did

not significantly affect potassium uptake from the soil.

Thorp and Hobbs (24) concluded from a greenhouse study that lime applications on alfalfa greatly increased the calcium content and the total calcium uptake of the plant, and that potassium uptake was also increased.

MacGregor, et al. (15) observed from field experiments of alfalfa that the addition of phosphate and potash fertilizers affected the phosphorus and potassium content of the plants. They found that by applying phosphate fertilizer, the phosphorus concentration of the plants and the total phosphorus removal was increased. Potash fertilization had little effect on phosphorus content of the plant, but greatly increased the potassium concentration and total uptake of potassium.

Longevity of stand of alfalfa has also been related to the potassium fertilization of the crop (2,11,12,23). Work done by Gerwig (11) showed that potassium fertilization was the key to high yields and long life of alfalfa stands. This was concluded from a five-year study which included fertilizer treatments of 0-200 pounds of nitrogen, 0-400 pounds of P_2O_5 , and 0-400 pounds of K_2O per acre in various combinations. Increases in yield and in number of plants per square foot were recorded with each increment of K_2O applied up to the 200-pound level. Higher rates were not beneficial. On check plots receiving no K_2O , potassium deficiency decreased stand as much as 98 per cent during the five-year study.

When a potassium fertilizer is added to the soil, the potassium

ion reacts rapidly with soil colloids by a base-exchange process, displacing other ions. The exchange of bases between the soil and the soil solution is assumed to be fairly rapid. The reaction of potassium with the soil colloids results in its immediate retention by the soil. In turn, potassium can be removed from this form of combination by other cations including hydrogen ions produced as a result of respiration by roots and soil micro-organisms. By this ion exchange process, potassium is taken from the colloidal complex of the soil and utilized by the plant (6).

For best growth of alfalfa, the amount of exchangeable potassium in a given soil is very important since it is from the soil and fertilizers added to the soil that a plant gets the nutrients necessary for its growth. Bear (2) has suggested that the critical level of potassium for alfalfa soils is 80 pounds of exchangeable potassium per two million pounds soil. His work also gave evidence supporting the concept that the exchange complex of the ideal alfalfa soil should contain about 65 per cent calcium, 10 per cent magnesium, 5 per cent potassium, and 20 per cent hydrogen. Such a soil would have a pH of about 6.5.

It was found in work done by Munsell (17) that annual applications of 200 pounds of 60 per cent muriate of potash maintained the most uniform concentration of soluble potassium throughout the plow layer. He concluded this by analyzing plots at one-inch intervals vertically through the six-inch plow layer. This work also revealed that under all treatments, the concentration of available potassium decreased with increasing soil depth.

Greenhouse experiments by Halstead, et al. (13) showed that ex-

exchangeable potassium in four of six soils analyzed at depths of 0-7 inches, 7-14 inches, and 14-21 inches did not vary appreciably between the surface and subsurface samples. However, water-soluble potassium decreased with depth in most instances. The soils sampled had been fertilized with 200 pounds K_2O per acre, 200 pounds P_2O_5 per acre, or with both. All fertilizers were placed in the soil to a depth of two inches. Along with results of potassium analysis, it was found that the relative amount of total phosphorus in surface and subsurface samples varied with the soil, the greatest variation being an increase of phosphorus in sandy soil with depth.

A study by Bradfield, et al. (5) related the response of alfalfa to various potassium fertilizers. Approximately 400 soil samples were analyzed for potassium. The results showed that on 85 per cent of the soils tested, those which tested less than 80 pounds available potassium per acre gave yield increases varying from 20 to 123 per cent when potassium fertilizer was added.

In root development studies on a Cumberland soil by Long (14), it was suggested that the low exchangeable potassium throughout the depth of rooting, along with acid soil reaction in the lower part of the solum probably accounted for the shallow root system of alfalfa and a decline in hay yield from 4.26 to 2.59 tons per acre on that particular soil over a three year period even through the reaction of the surface layer of the soil was considered to be satisfactory for alfalfa growth. This is in agreement with the work of Pohlman (19) which pointed out that increases in yield of alfalfa obtained by raising the pH of the

surface soil to 65 was dependent on the lime status of the subsurface horizons.

Investigations by Gammon (9,10) showed that maintaining soil reaction at a pH of 6.2 increased soil retention of potassium, but that liming soil to a pH above 6.5 may result in a loss of soil potassium by leaching.

CHAPTER III

METHODS AND PROCEDURES

Four alfalfa experiments were used in this study. These were located at the Middle Tennessee, Highland Rim, Tobacco, and Main Experiment Stations.

Each experiment was on a different soil type. The types were Decatur silty clay loam, Dickson silt loam, Dunmore silt loam, and Maury silt loam.

The Decatur soil, which was located on the Main Station, is a Reddish-Brown Lateritic soil derived from limestone parent material. It is a deep, well drained upland soil which is well suited for growth of alfalfa.

The Dickson soil, located on the Highland Rim Station, is a Red-Yellow Podzolic soil with a distinct fragipan, which has developed in residuum from cherty limestones capped with shallow loess. The fragipan varies in depth from 20 to 30 inches. In this case it was 24 inches deep.

The Dunmore soil, located on the Tobacco Station, is also a Red-Yellow Podzolic soil. It is derived from argillaceous limestones or dolomitic limestones containing thin lens of shaly material. This is a well drained upland soil of the Northern Appalachian Valley.

The Maury soil, located on the Middle Tennessee Station, is another Red-Yellow Podzolic soil but with some characteristics of the Reddish-Brown Lateritic group. Maury soils have developed in residuum

from highly phosphatic limestones. They are well drained soils of the Outer Basin, and are well adapted for alfalfa production.

The experiments were initiated at the Middle Tennessee Experiment Station in the fall of 1952 and at the other locations in the fall of 1953. The Buffalo variety of alfalfa was used in each experiment, seeded at the rate of 20-25 pounds per acre. All soils received initial fertilization as need was indicated by the 1952 soil test procedures.

Annual fertilization treatments consisted of 0, 60, 120, and 180 pounds P_2O_5 ; 0, 100, 200, 300, and 400 pounds of K_2O per acre. These rates were combined to give a 4×5 complete factorial plot design on the Decatur, Dickson, and Dunmore soils. A randomized block design was used on the Maury silt loam since no phosphate was applied to this soil with a high native phosphate content.

Three replications were made of each treatment on the Decatur, Dickson, and Dunmore soils. Four replications were made on the Maury soil. Only two replications were sampled in the Dickson experiment since one replication had been discontinued in 1957 because excessive water caused loss of stand.

Soil samples were taken from each plot in each experiment and analyzed for available phosphorus, exchangeable potassium and pH. Selected samples from each experiment were analyzed for calcium and magnesium.

All soil sampling was done with soil sampling tubes. Samples were taken at 0-1, 1-3, 3-6, 6-12, 12-18, 18-24, 24-30, and 30-36 inches on the Maury and Decatur soils. The Dickson was sampled only to a depth

of 24 inches since the fragipan in this soil could not be further penetrated with a sampling tube at the time of sampling. The Dunmore was sampled to a depth of only 12 inches because of the high amount of chert which prevented deeper sampling. Six cores were obtained from each plot and the six samples from each depth sampled were then transferred to paper bags and air dried. All samples were then ground, sieved through a 2 mm sieve, mixed, and stored in glass bottles with plastic caps. The Maury and Decatur soils were sampled in February, 1958, the Dunmore in March, 1958, and the Dickson in October, 1958.

In soil analysis, phosphorus was determined colorimetrically using the Beckman B spectrophotometer. A Perkin-Elmer flame photometer was used for potassium determinations, and a Beckman DU flame spectrophotometer with a photomultiplier attachment was used for calcium and magnesium determinations. A Beckman Model G pH meter was used for pH determinations.

CHAPTER IV

RESULTS

Potassium Soil Test Results

Potassium soil test data are presented in appendixes D through G. A graphic summary of potassium soil test data is presented in figures 1 through 4.

Exchangeable potassium levels of the Maury soil from various treatments show that the potassium level increased as the amount of annual potassium fertilization was increased. The greatest concentration of exchangeable potassium was found to be in the 0-6 inch plow layer in every treatment. It was observed from the 300 and 400 pound K_2O per acre treatment that the exchangeable potassium level of the 6-12 inch layer had increased slightly over values of the 0, 100, and 200 pound per acre treatments.

Potassium soil test data from the Decatur soil showed that as potassium application was increased, the exchangeable potassium concentration was also increased. The 0-6 inch plow layer contained the greatest concentration of exchangeable potassium. Only in the 400 pound K_2O per acre treatment was an appreciable difference in concentration of exchangeable potassium below the plow layer noticed. This increased potassium level below the plow layer reached only to the 12-inch depth.

Data from the Dunmore soil showed that exchangeable potassium level increased as treatment with potassium was increased. The greatest concentration of exchangeable potassium was found to be in the 0-6 inch

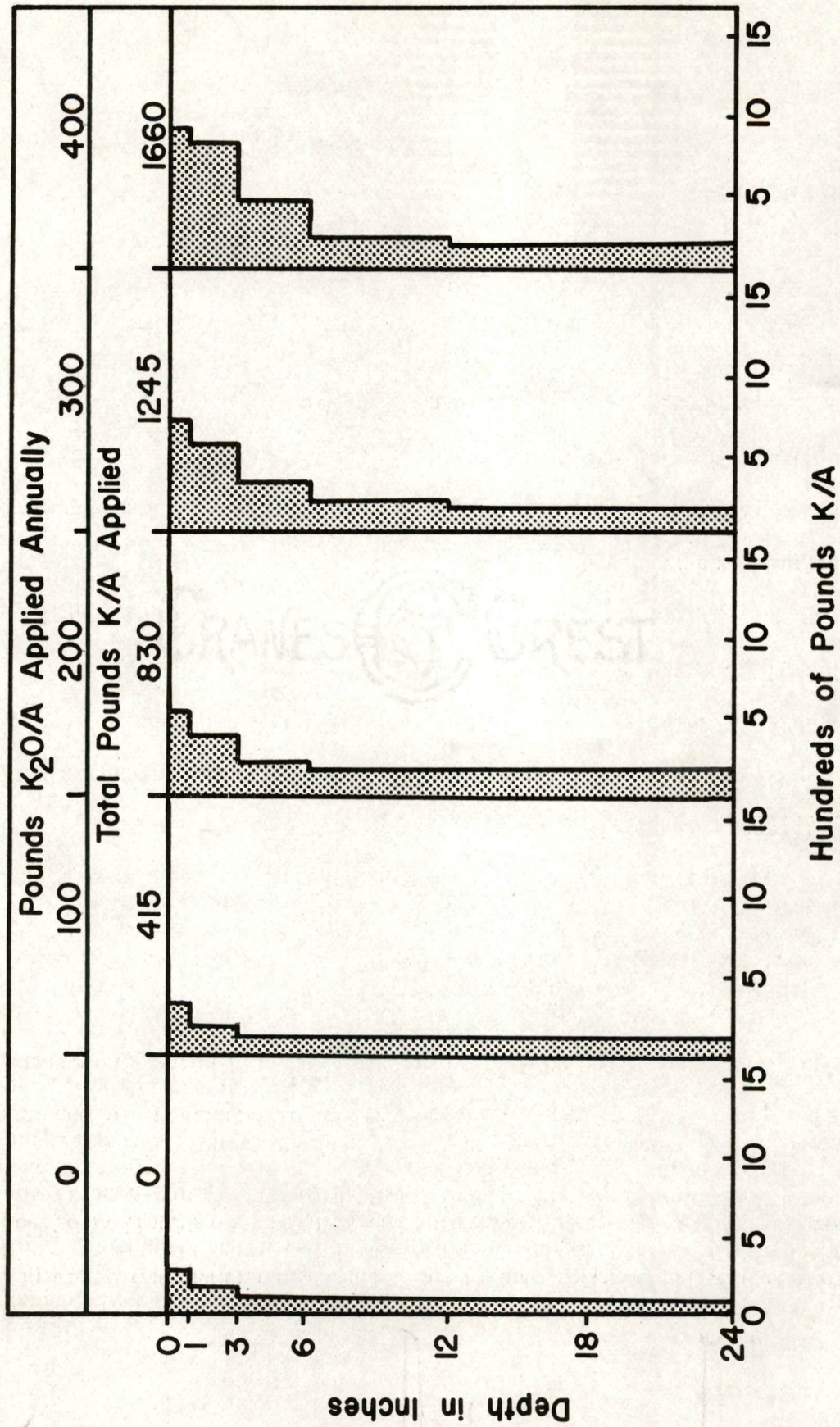


Figure 1.—Potassium soil test values at several depths in Maury silt loam after five annual topdressings of potash at five rates.

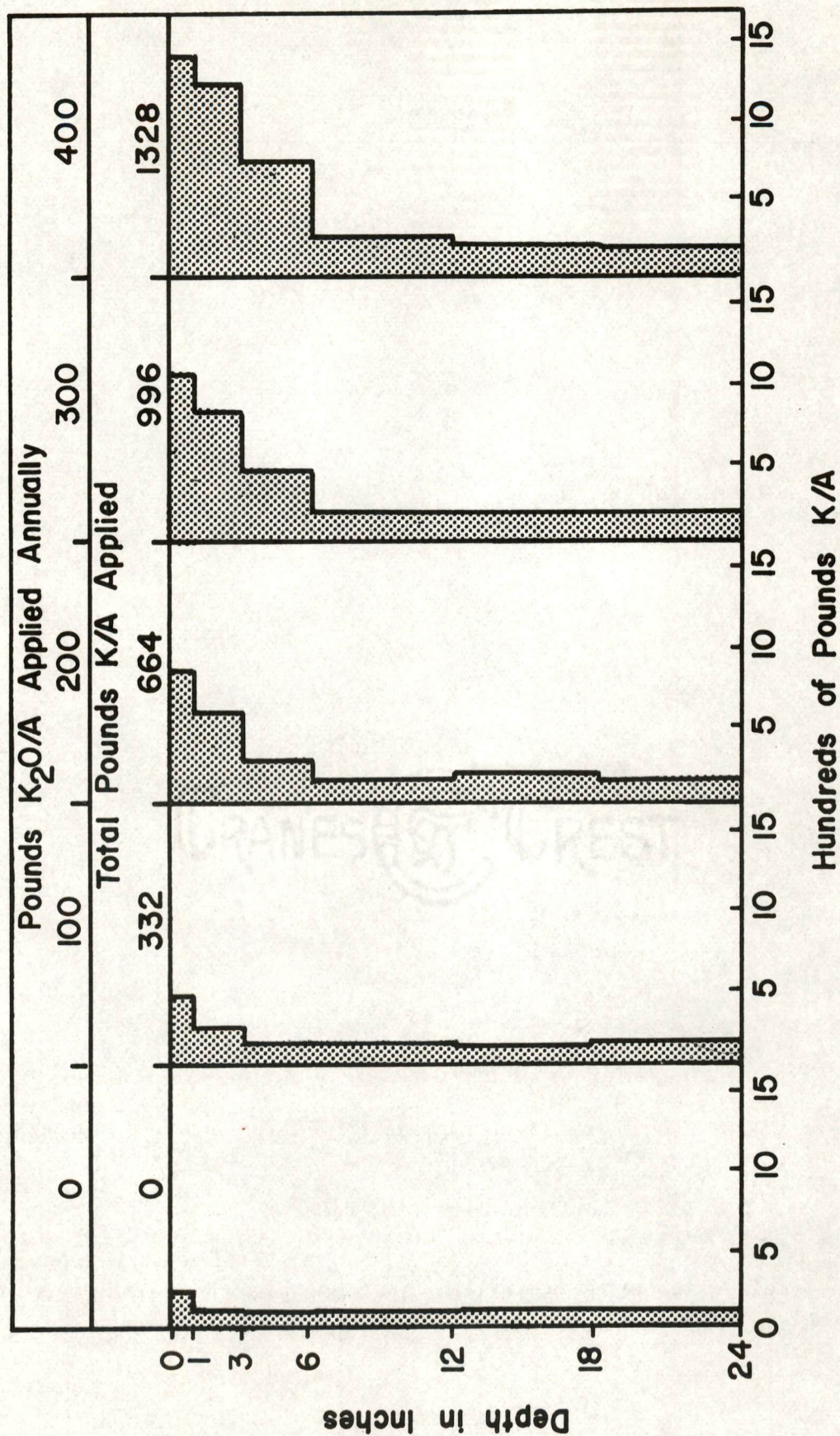


Figure 2.—Potassium soil test values at several depths in Decatur silty clay loam after four annual topdressings of potash at five rates.

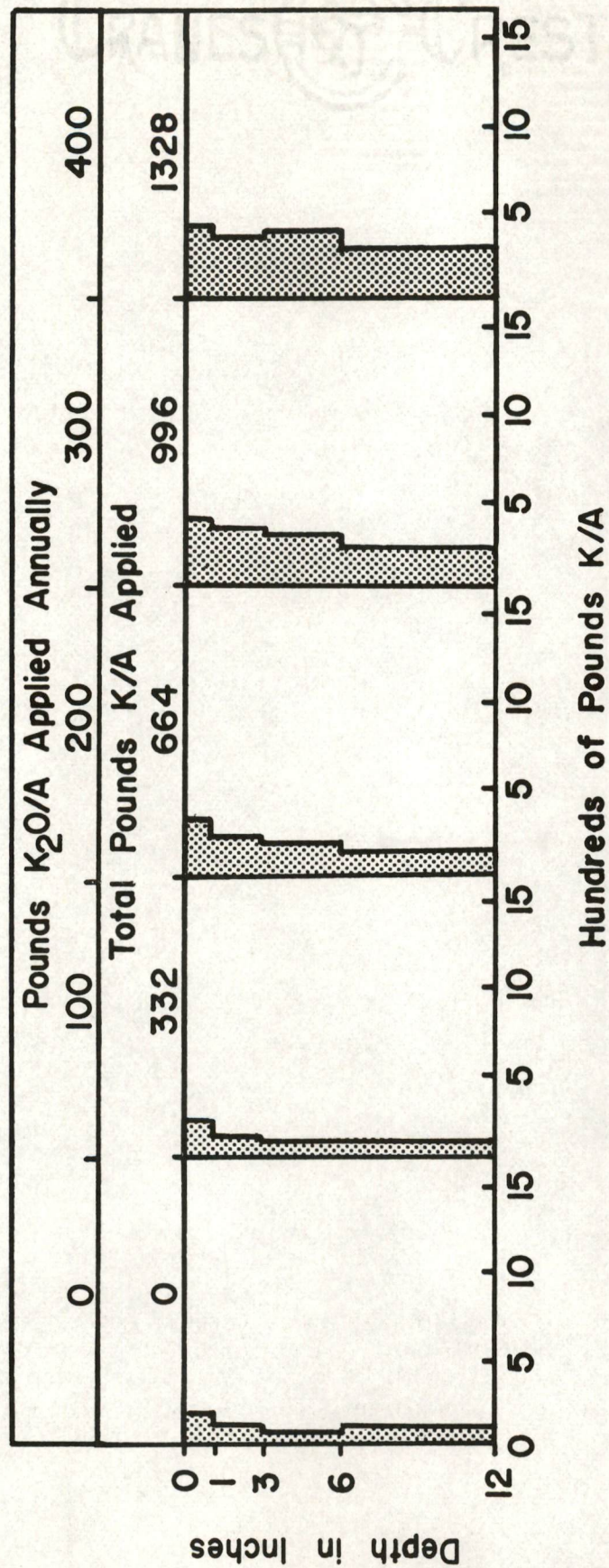


Figure 3.—Potassium soil test values at several depths in Dunmore silt loam after four annual topdressings of potash at five rates.

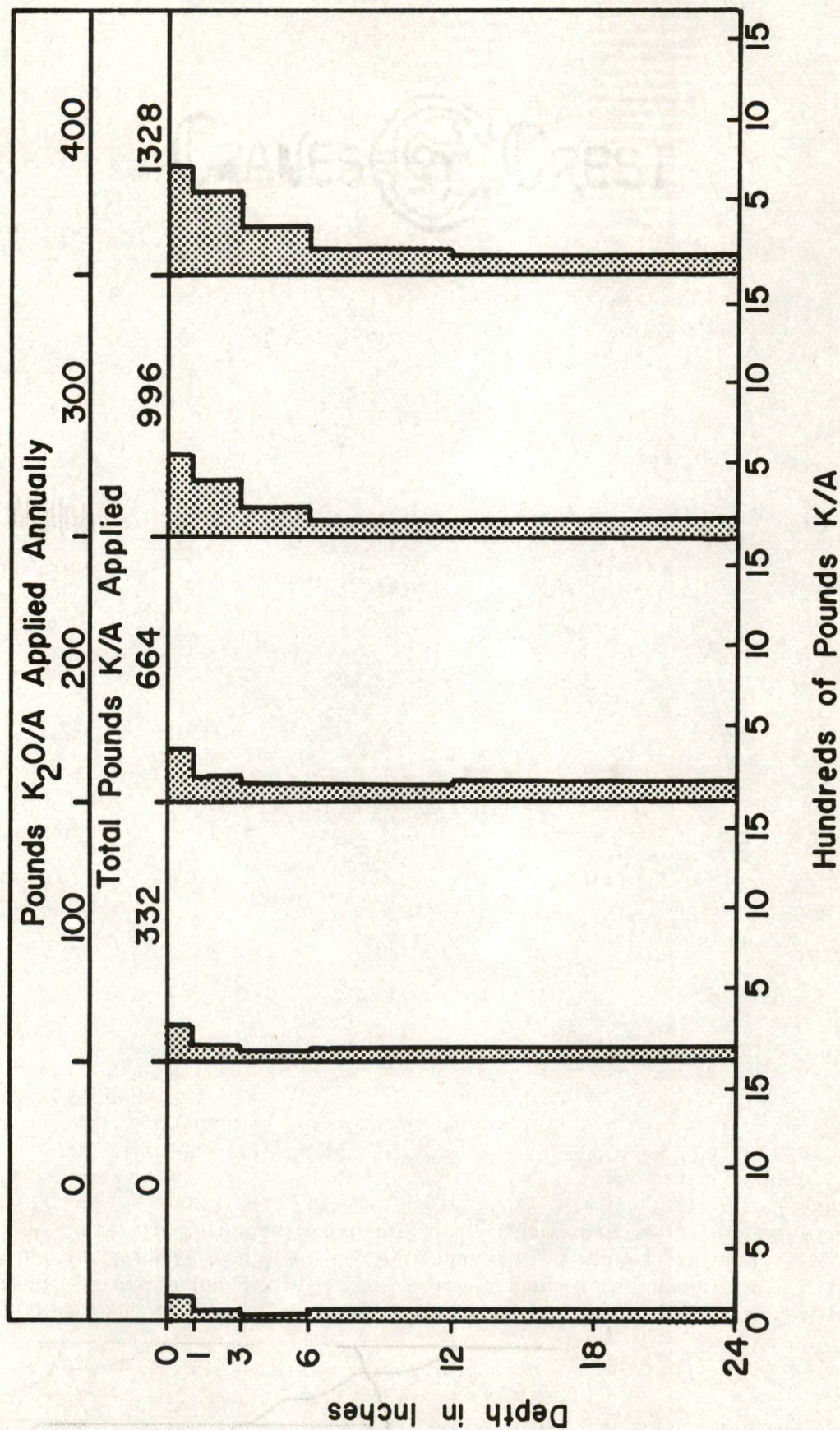


Figure 4.—Potassium soil test values at several depths in Dickson silt loam after four annual topdressings of potash at five rates.

plow layer, however, it was evident that the exchangeable potassium level of the 6-12 inch layer also increased as application of potassium was increased.

In the Dickson soil, concentration of exchangeable potassium was found to increase as rate of potassium application was increased. The highest level of exchangeable potassium was found in the 0-6 inch plow layer. Only the 400 pound K_2O per acre treatment showed an increase in exchangeable potassium in the 6-12 inch layer.

Phosphorus Soil Test Results

Available phosphorus soil test data are presented in appendixes D through G. A graphic summary of these data is shown in figures 5 through 7.

No data were reported for the Maury soil since no phosphate variable was used in that experiment.

Available soil phosphorus in the Decatur soil increased as application of phosphorus was increased. The greatest concentration of available phosphorus was found in the 0-3 inch layer. Available phosphorus in the depths below 6 inches was essentially the same in every treatment.

Data from the Dunmore soil indicate that the largest amount of available soil phosphorus was concentrated in the 0-6 inch plow layer. The amount of available phosphorus in that layer increased as phosphate treatment was increased. Available phosphorus levels in the 6-12 inch layer were essentially the same in every treatment.

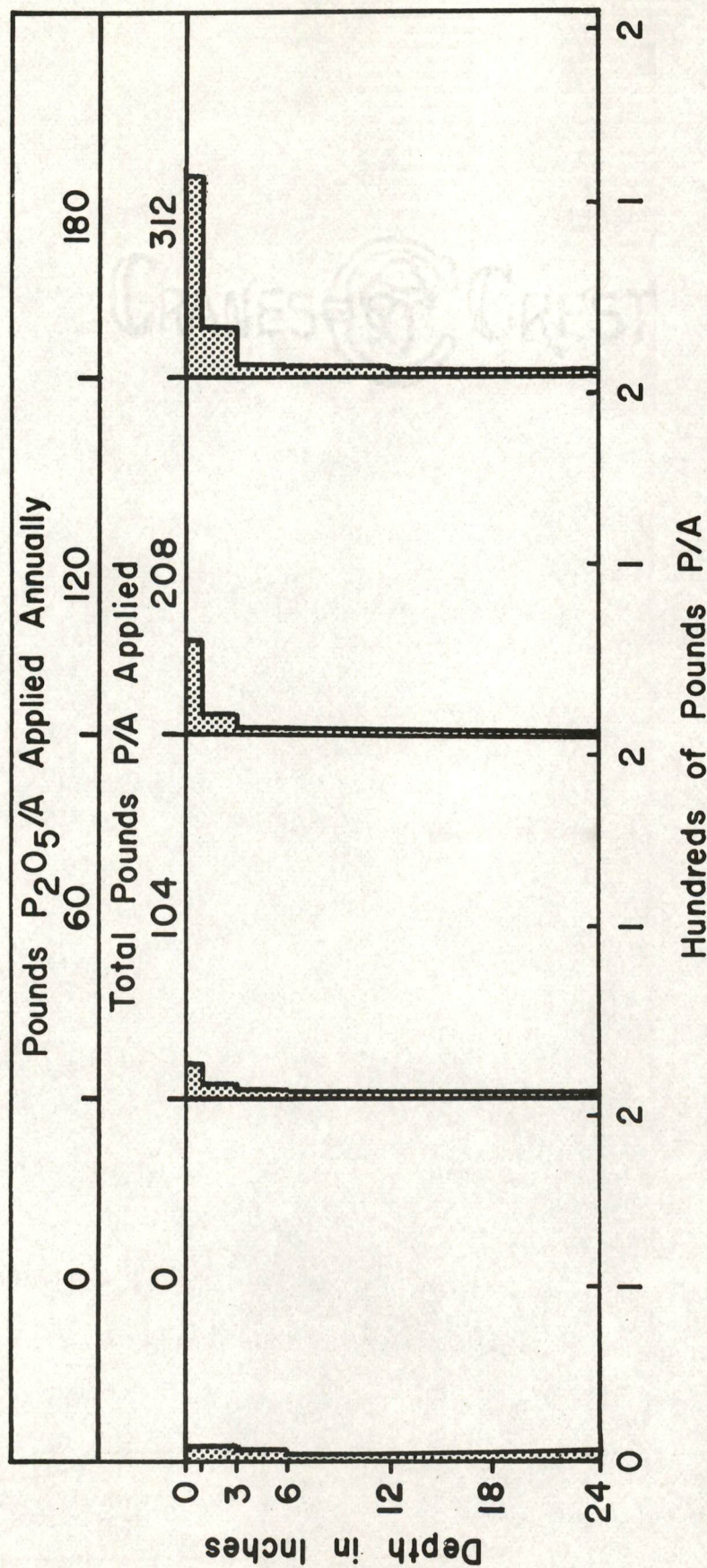


Figure 5.—Phosphorus soil test values at several depths in Decatur silty clay loam after four annual topdressings of phosphate at four rates.

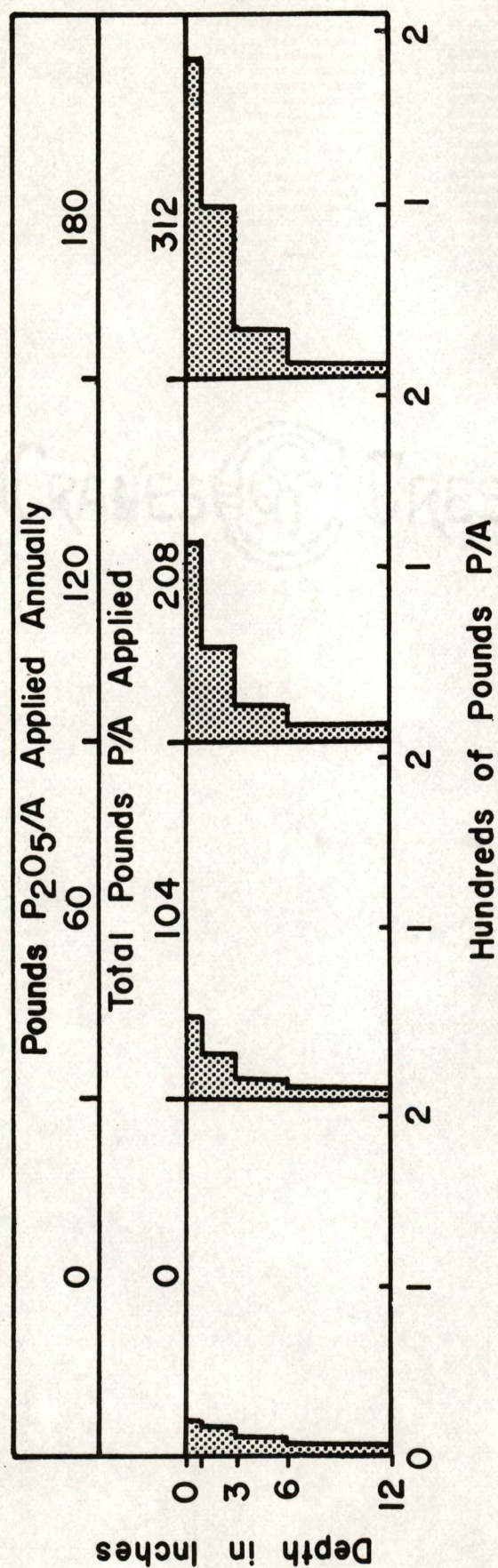


Figure 6.—Phosphorus soil test values at several depths in Dunmore silt loam after four annual topdressings of phosphate at four rates.

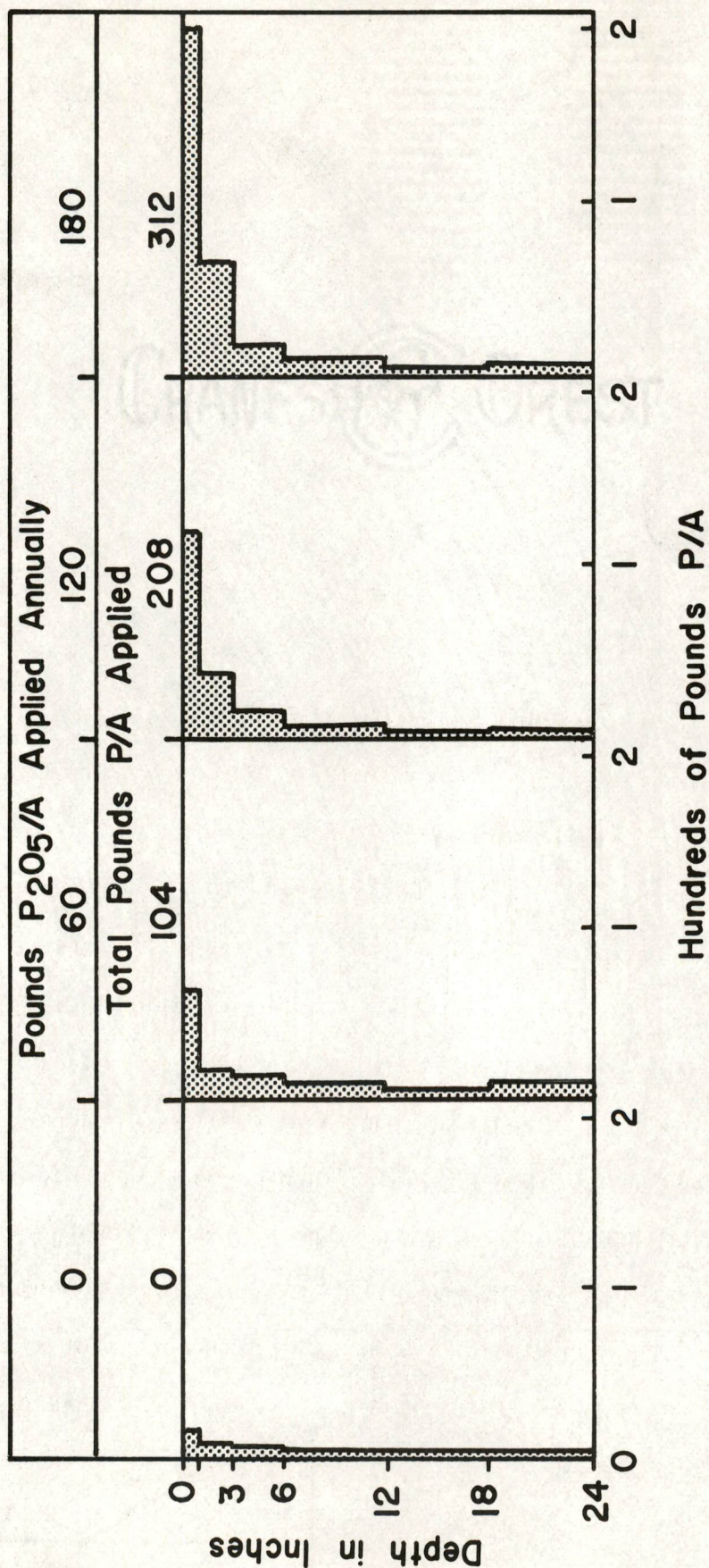


Figure 7.—Phosphorus soil test values at several depths in Dickson silt loam after four annual topdressings of phosphate at four rates.

In the Dickson soil, available phosphorus was found to be more highly concentrated in the 0-3 inch layer. In every treatment, available phosphorus values decreased with each successive sampling depth to 18 inches, where there was then a slight increase over the preceding layer.

Soil pH Level Data

Soil pH data are presented in appendixes D through G. For comparison purposes, only those pH data from annual treatments with 0, 200, and 400 pounds K_2O per acre were used. These data are shown in figures 8 through 11.

On the Maury soil, the fertilizer treatments had no effect on pH. Generally, the pH was near 6.0 from the surface downward to a depth of 18 inches where it then gradually declined to around 5.0 at a depth of 36 inches.

Data from the Decatur soil showed that there was generally no effect on pH attributable to differences in potassium treatment. The noticeable change was the tendency for the pH of the 3-18 inch layer to be higher than that of the 0-3 inch layer. After the 18 inch depth, pH declined from a general value of about 6.4 to a value of around 5.0 at the 36-inch depth.

Values for the Dunmore soil showed that there was essentially no effect on pH due to rate of potassium application. It was observed that pH gradually declined from around 6.3 at the surface to around 6.0 at the 6-inch depth. Reaction of the 6-12 inch layer dropped to around pH 5.2.

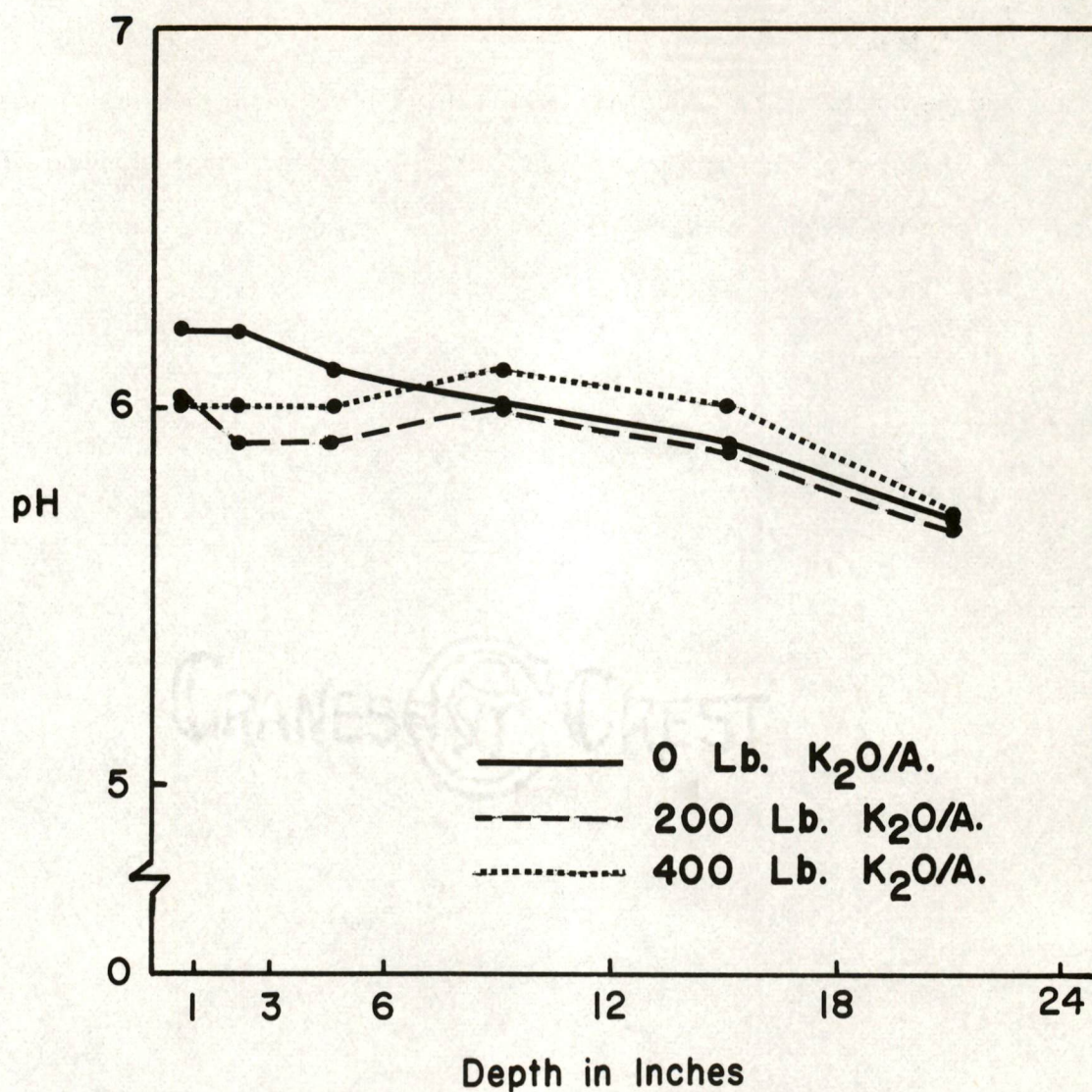


Figure 8.—Soil pH values at several depths in Maury silt loam after five annual topdressings of potash at various rates.

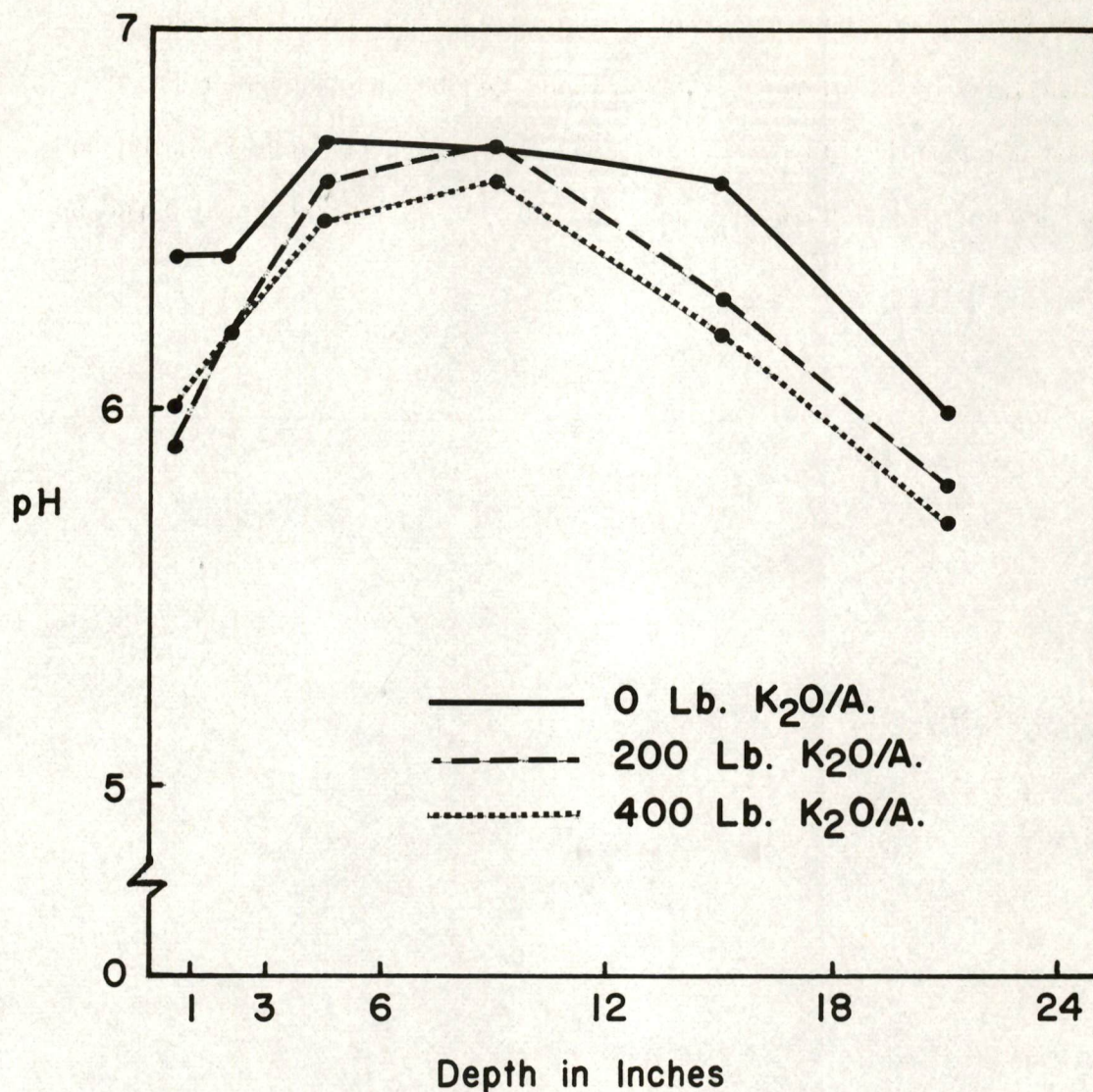


Figure 9.—Soil pH values at several depths in Decatur silty clay loam after four annual topdressings of potash at various rates.

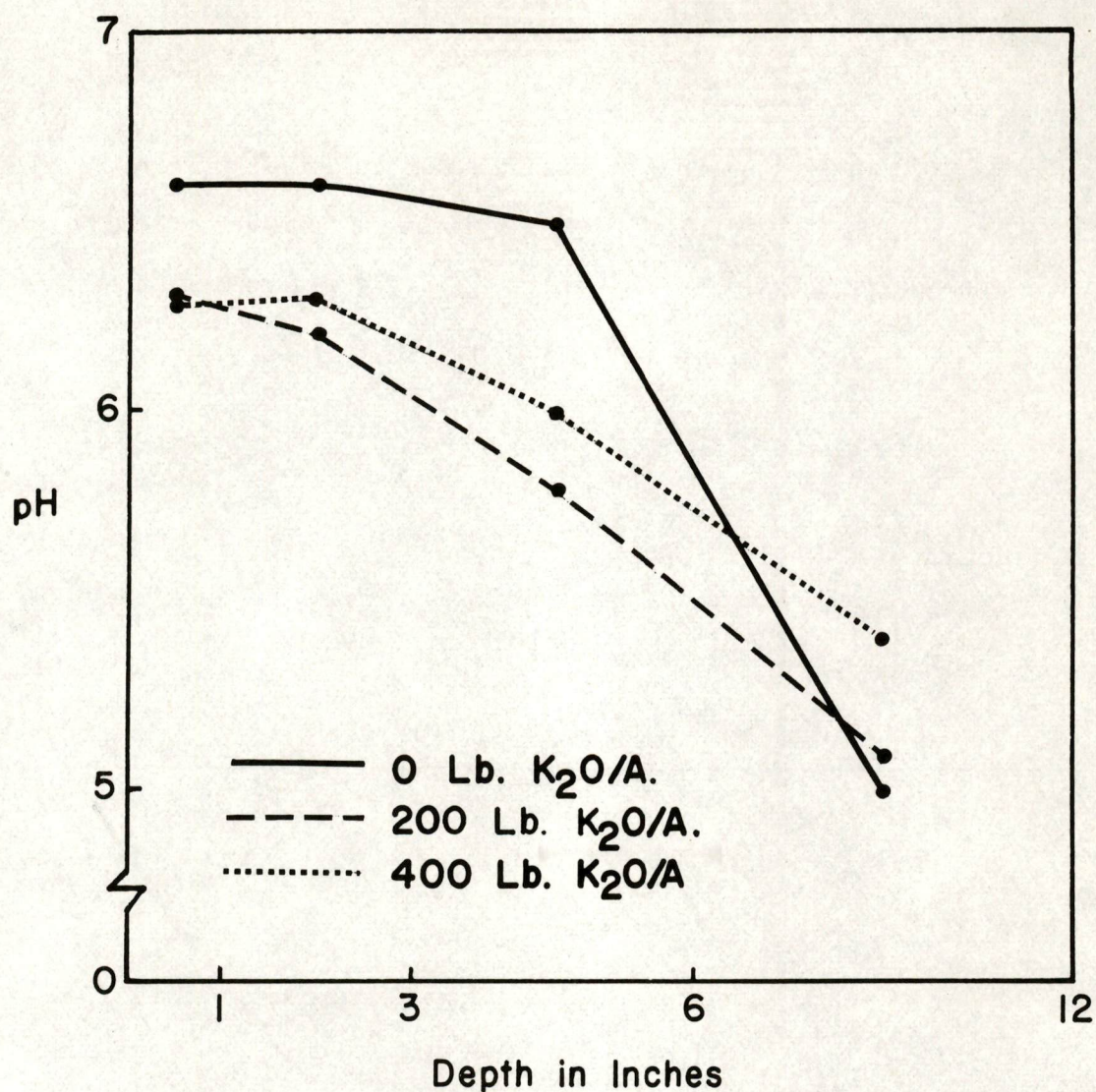


Figure 10.—Soil pH values at several depths in Dunmore silt loam after four annual topdressings of potash at various rates.

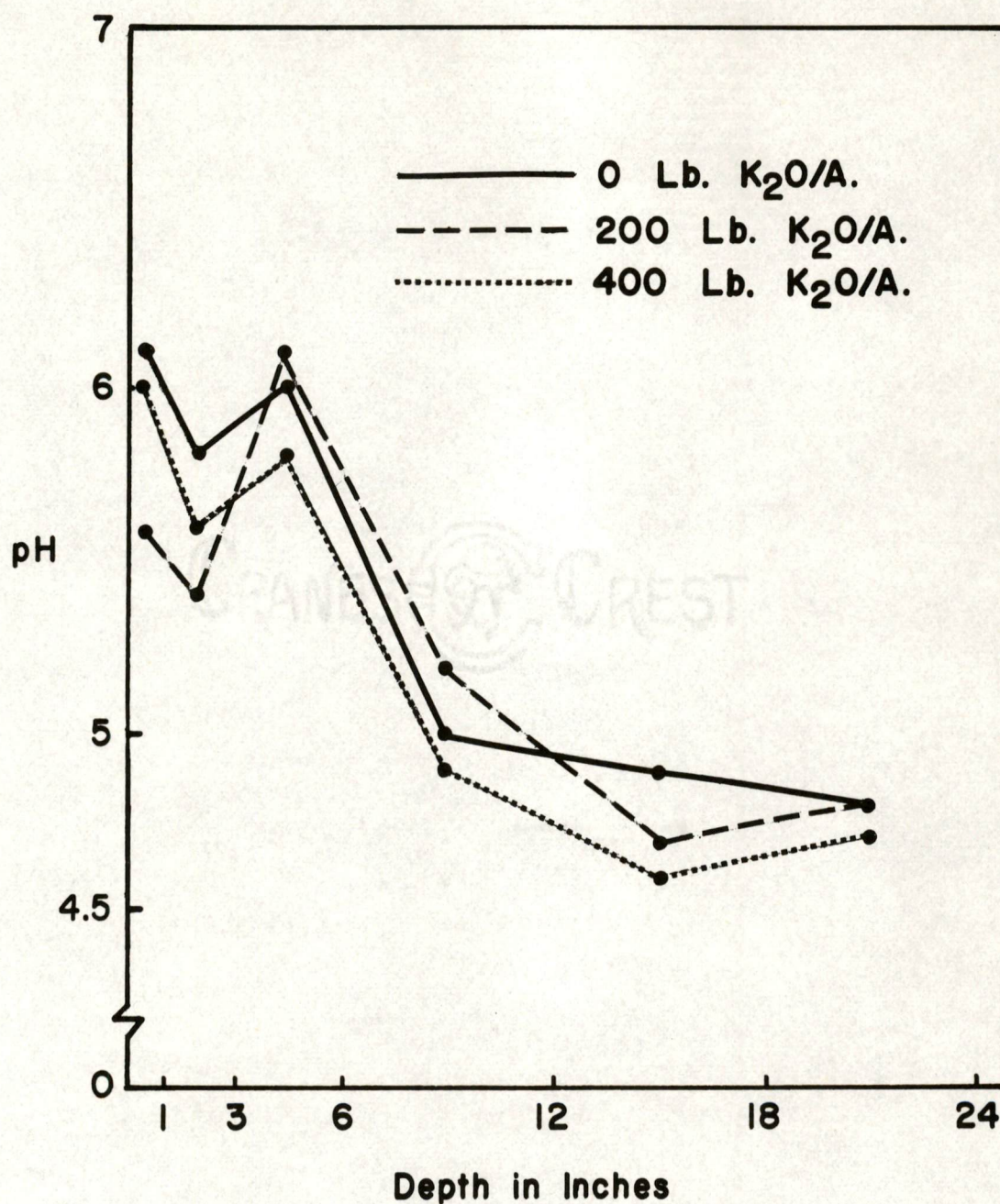


Figure 11.—Soil pH values at several depths in Dickson silt loam after four annual topdressings of potash at various rates.

Soil reaction data from the Dickson soil indicated that various annual applications of K_2O per acre did not appreciably affect pH values at various depths. It was evident that pH values were relatively low through the Dickson soil which varied in reaction from around pH 5.8 - 5.9 at the surface to around pH 4.8 at a depth of 24 inches.

Calcium and Magnesium Soil Test Data

Calcium and magnesium soil test results are presented in appendixes D through G.

Exchangeable calcium and magnesium was determined on all 200-pound K_2O per acre treatments in each soil.

These data show on each soil that exchangeable calcium and magnesium values varied slightly as depth of sampling was increased.

Yield of Alfalfa Hay

Yield data for 1957 and 1958 are summarized in Tables 1 through 4. Yields each year on the Maury soil represent the sum of four cuttings. A comparison of the 0-pound potassium treated plots with an average of those plots receiving potassium showed a significant difference in yield. The least significant difference at the .05 level of probability was 1.0 ton per acre.

The same general results were noted in the 1958 Maury yield data. The least significant difference at the .05 level of probability was 0.76 ton per acre.

A total of five cuttings made up the 1957 yield from the Decatur soil. A significant difference in yield due to potassium over no

TABLE I

AVERAGE YIELD OF ALFALFA FROM MAURY SILT LOAM OF THE 5TH AND
6TH PRODUCTIVE YEARS AFTER VARIOUS RATES OF
ANNUAL TOPDRESSING

Tmt No.	Annual Treatment	Average Yield in Tons Air Dry Hay/Acre	
		1957	1958
1	0-0-0	2.99	2.01
2	0-0-100 applied in Feb.-Mar.	4.65	3.13
3	0-0-200 " " " "	3.93	2.45
4	0-0-300 " " " "	4.62	3.85
5	0-0-400 " " " "	4.50	3.95
6	0-0-100 applied after 1st cutting	3.74	1.94
7	0-0-200 " " " "	3.55	1.48
8	0-0-300 " " " "	3.86	2.57
9	0-0-400 " " " "	4.18	1.86
L.S.D. (.05)		1.00	1.08

1957
Rate of Application of K_2O

100 = 4.19
200 = 3.74
300 = 4.24
400 = 4.34
L.S.D.
(.05) = N.S.

1958
Rate of Application of K_2O

100 = 2.54
200 = 1.96
300 = 3.21
400 = 2.91
L.S.D.
(.05) = 0.76

Time of Application

K_2O in February-March = 4.42
After first cutting = 3.83
L.S.D. (.05) = 0.50

Time of Application

K_2O in February-March = 3.34
After first cutting = 1.96
L.S.D. (.05) = 0.54
(.01) = 0.73

TABLE II

AVERAGE YIELD OF ALFALFA FROM DECATUR SILTY CLAY LOAM OF 4TH
AND 5TH PRODUCTIVE YEARS AFTER VARIOUS RATES OF
ANNUAL TOPDRESSING

Tmt. No.	Treatment	Average Yield in Tons Air Dry Hay/Acre	
		1957	1958
1	0-0-0	2.49	2.19
2	0-0-100	2.58	2.37
3	0-0-200	2.95	2.81
4	0-0-300	3.55	2.79
5	0-0-400	3.10	2.59
6	0-60-0	2.87	2.16
7	0-60-100	4.69	3.57
8	0-60-200	4.37	4.21
9	0-60-300	5.02	3.37
10	0-60-400	5.32	3.53
11	0-120-0	4.11	3.10
12	0-120-100	5.71	3.86
13	0-120-200	5.17	4.20
14	0-120-300	5.92	3.91
15	0-120-400	5.72	3.75
16	0-180-0	4.04	2.83
17	0-180-100	5.00	3.38
18	0-180-200	5.31	3.48
19	0-180-300	5.54	3.81
20	0-180-400	6.60	5.13
L.S.D. (.05)		1.35	1.06
(.01)		1.80	1.42

1957		1958	
Rates of P ₂ O ₅	Rates of K ₂ O	Rates of P ₂ O ₅	Rates of K ₂ O
0 = 2.93	0 = 3.38	0 = 2.55	0 = 2.57
60 = 4.46	100 = 4.50	60 = 3.37	100 = 3.30
120 = 5.33	200 = 4.45	120 = 3.77	200 = 3.68
180 = 5.30	300 = 5.01	180 = 3.73	300 = 3.47
L.S.D.	400 = 5.19	L.S.D.	400 = 3.75
(.05)=0.60	L.S.D.	(.05)=0.47	L.S.D.
(.01)=0.80	(.05)=0.67	(.01)=0.63	(.05)=0.53
	(.01)=0.90		(.01)=0.71

TABLE III

AVERAGE YIELD OF ALFALFA FROM DUNMORE SILT LOAM OF THE 4TH AND
5TH PRODUCTIVE YEARS AFTER VARIOUS RATES OF
ANNUAL TOPDRESSING

Tmt. No.	Annual Tmt. Lbs./A	Average Yield in Tons Air Dry Hay/Acre	
		1957	1958
1	0-0-0	2.36	2.94
2	0-0-100	2.45	2.68
3	0-0-200	2.29	2.84
4	0-0-300	2.92	2.87
5	0-0-400	2.93	3.03
6	0-60-0	2.39	2.55
7	0-60-100	2.79	2.99
8	0-60-200	3.02	2.99
9	0-60-300	3.07	3.13
10	0-60-400	3.50	3.20
11	0-120-0	2.39	3.03
12	0-120-100	2.89	3.03
13	0-120-200	3.10	2.94
14	0-120-300	3.21	3.06
15	0-120-400	3.16	2.94
16	0-180-0	2.67	2.82
17	0-180-100	3.05	2.99
18	0-180-200	3.13	2.98
19	0-180-300	3.17	3.18
20	0-180-400	3.20	2.95
L.S.D. (.05)		.57	N.S.
(.01)		.77	N.S.

1957		1958	
Rates of P ₂ O ₅	Rates of K ₂ O	Rates of P ₂ O ₅	Rates of K ₂ O
0 = 2.59	0 = 2.45	0 = 2.87	0 = 2.83
60 = 2.95	100 = 2.80	60 = 2.97	100 = 2.92
120 = 2.95	200 = 2.88	120 = 3.00	200 = 2.94
180 = 3.04	300 = 3.10	180 = 2.98	300 = 3.06
L.S.D.	400 = 3.20	L.S.D.	400 = 3.03
(.05) = 0.18	L.S.D.	(.05) = N.S.	L.S.D.
(.01) = 0.24	(.05) = 0.29		(.05) = N.S.
	(.01) = 0.38		

TABLE IV

AVERAGE YIELD OF ALFALFA FROM DICKSON SILT LOAM OF 4TH AND 5TH
PRODUCTIVE YEARS AFTER VARIOUS RATES OF
ANNUAL TOPDRESSING

Tmt. No.	Treatment	Average Yield in Tons Air Dry Hay/Acre	
		1957	1958
1	0-0-0	2.06	0
2	0-0-100	3.12	1.72
3	0-0-200	3.16	2.14
4	0-0-300	3.46	3.67
5	0-0-400	4.02	3.85
6	0-60-0	2.11	0
7	0-60-100	3.65	2.48
8	0-60-200	3.85	4.00
9	0-60-300	4.07	4.11
10	0-60-400	4.20	4.11
11	0-120-0	2.13	0
12	0-120-100	3.31	2.43
13	0-120-200	4.06	4.11
14	0-120-300	3.79	4.34
15	0-120-400	3.90	4.54
16	0-180-0	1.96	0
17	0-180-100	3.38	2.29
18	0-180-200	3.97	3.89
19	0-180-300	3.93	4.86
20	0-180-400	3.80	4.20
L.S.D. (.05)		N.S.	0.89
(.01)		N.S.	1.24

1957		1958	
Rates of P_2O_5	Rates of K_2O	Rates of P_2O_5	Rates of K_2O
0 = 3.16	0 = 2.06	0 = 2.84	0 = 0.00
60 = 3.57	100 = 3.36	60 = 3.67	100 = 2.23
120 = 3.44	200 = 3.76	120 = 3.85	200 = 3.53
180 = 3.41	300 = 3.81	180 = 3.81	300 = 4.24
L.S.D.	400 = 3.98	L.S.D.	400 = 4.17
(.05)=N.S.	L.S.D.	(.05)=0.45	L.S.D.
	(.05)=0.31	(.01)=0.63	(.05)=0.45
	(.01)=0.42		(.01)=0.63

potassium was obtained at the 100-pound K_2O per acre treatment where the least significant difference at the .05 level of probability was 0.67 ton per acre. A significant difference in yield due to phosphorus additions was found at the 60-pound P_2O_5 per acre treatment where the least significant difference between phosphorus treatments at the .05 level of probability was 0.60 ton per acre.

Yield of hay from the Decatur soil in 1958 was obtained from four cuttings. Least significant difference for rates of phosphorus was 0.47 per acre at the .05 level of probability. Least significant difference between rates of potassium was 0.53 ton per acre at the .05 level of probability. Significance in yield due to potassium was found at the 100-pound K_2O per acre treatment while significance in yield due to phosphorus additions was found at the 60-pound P_2O_5 per acre treatment.

In 1957 yield data from the Dunmore soil showed that a significant difference in potassium applications was found at the 100-pound K_2O per acre treatment where the least significant difference at the .05 level of probability was 0.29 ton per acre. Significance in yield due to phosphorus addition was found at the 60-pound P_2O_5 per acre treatment where least significant difference at the .05 level of probability was 0.18 ton per acre. A total of three cuttings made up the yield.

In 1958, Dunmore yield data showed no significant difference between either rates of K_2O or rates of P_2O_5 at the .05 level of probability.

Dickson yield data in 1957 showed that there was a significant increase in yield due to phosphorus fertilization at the 60-pound P_2O_5

per acre treatment and at the 100-pound K_2O per acre treatment. Least significant difference at the .05 level of probability was 0.71 ton per acre.

Similar results were obtained in 1958 on the Dickson soil. Least significant difference for 1958 data was 0.45 ton per acre at the .05 level of probability.

Correlation of Soil Test Data and 1957 Yield Data

The 1957 yield data were correlated with soil test values using the least squares regression method as outlined by Ostle (18), Grout (7), and Tintner (25).

The equation $Y = f(K_{0-1"} + K_{1-3"} + K_{3-6"} + K_{6-12"})$ was used to estimate what per cent of the variation in yield, the potassium soil test values would explain. R^2 values, or the percent variation of yield explained by potassium soil test values are presented in Table V. Values for r^2 , or per cent variation of yield explained by potassium soil test values of any individual soil layer, are also presented in Table V. Values for c_{ij} with resultant partial regression coefficients and Ex_{1y} are shown in appendix H through J.

Data showed that the greatest percent of variation in yield explained by soil test potassium values from the layers to a depth of 12-inches was on the Dunmore soil, followed by Decatur, Dickson, and Maury soils. When considering only values of the layers to a depth of 6-inches, the data on Dunmore explained more than the data on Decatur, but the data on Maury gave a greater per cent of explanation than data on Dickson.

It was shown from r^2 values that soil test potassium values of the 3-6 inch layer gave the greatest amount explanation of variation in yield due to potassium soil test values in the Dunmore, Decatur, and Dickson

TABLE V

R^2 and r^2 Values Where $Y = f(K_{0-1''} + K_{1-3''} + K_{3-6''} + K_{6-12''} +)$ and $Y = f(K_{0-1''} + K_{1-3''} + K_{3-6''} + K_{6-12''} + K_{12-18''} + K_{18-24''} + K_{24-30''} + K_{30-36''})$.

Soil	r^2										R^2
	0-1''	1-3''	3-6''	6-12''	12-18''	18-24''	24-30''	30-36''			
Dunmore	.305	.222*	.352	.106*	....	....	....	....			.329
Decatur	.055	.0001	.075	.035	....	....	....	....			.165
Dickson	.026*	.073*	.105	.045	....	....	....	....			.051
Maury	.000006*	.022	.0001	.003*	.0006*	.0005	.014	.004*			.029

* r^2 values from negative r values

soils. The 1-3 inch layer potassium soil test values gave the greatest amount of explanation of variation in yield on the Maury soil.

The equation $Y = f(K_{0-1"} + K_{1-3"} + K_{3-6"} + K_{6-12"} + K_{12-18"} + K_{18-24"} + K_{24-30"} + K_{30-36"})$

was used in an attempt to explain variation in yield due to potassium soil test values of different soil layers in the Maury soil. The R^2 value obtained was .030.

Yield equations were set up using potassium soil test values for each soil.

Using the general equation

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \dots + b_kX_k,$$

The yield data and soil potassium data from the Dunmore soil gave the equation

$$\hat{Y} = 2.032878 + 0.003977 X_1 - 0.003216 X_2 + 0.004109 X_3 - 0.002652 X_4.$$

The yield data and soil potassium data from the Decatur soil gave the equation

$$\hat{Y} = 2.447905 - 0.004308 X_1 + 0.002606 X_2 + 0.009896 X_3 + 0.009311 X_4.$$

The yield data and soil potassium data from the Dickson soil gave the equation

$$\hat{Y} = 3.010167 - 0.000749 X_1 - 0.001869 X_2 + 0.004426 X_3 + 0.006596 X_4.$$

The equation from using yield data and soil potassium data from the Maury soil was

$$\begin{aligned} \hat{Y} = & 3.754471 - 0.000139 X_1 + 0.000293 X_2 + 0.000097 X_3 - 0.000444 X_4 \\ & - 0.000191 X_5 + 0.000242 X_6 + 0.002393 X_7 - 0.000980 X_8. \end{aligned}$$

An explanation of variation in yield was also made using the equation $Y = f(P + K + P^2 + K^2 + PK)$.

Soil test values for the 0-6 inch layer were used for the available phosphorus and exchangeable potassium values in this equation. In using this equation all data were coded by dividing by 1000. R^2 values for each soil used in this equation are shown in Table VI. Dunmore gave the greatest amount of explanation in variation of yield using this equation. Decatur gave the next highest explanation, and Dickson the least.

From the general equation

$$\hat{Y} = b_0 + b_1 X_1 + b_2 X_2 + b_k X_k,$$

yield equations were set up for each soil used with this function.

Yield data and soil test data from the Dunmore soil gave the equation

$$\hat{Y} = -0.000678 - 0.009173 X_1 + 0.007903 X_2 + 0.000257 X_3 - 0.000012 X_4 - 0.000032 X_5.$$

Yield data and soil test data from the Decatur soil gave the yield equation

$$\hat{Y} = 0.001681 + 0.191531 X_1 + 0.006755 X_2 - 0.003830 X_3 - 0.000008 X_4 + 0.000080 X_5.$$

Yield data and soil test data from the Dickson soil gave the yield equation

$$\hat{Y} = 0.001228 + 0.062934 X_1 + 0.009859 X_2 - 0.000606 X_3 - 0.000010 X_4 - 0.000058 X_5.$$

TABLE VI

R^2 Values Where $Y = f(P_{0-6''} + K_{0-6''} + P^2_{0-6''} + K^2_{0-6''} + PK)$

Soil	R^2
Dunmore	.500
Decatur	.430
Dickson	.002

CHAPTER V

DISCUSSION AND CONCLUSIONS

Potassium Soil Test Data

Exchangeable soil potassium as measured by soil test was concentrated in the 0-6 inch plow layer in every experiment. These soil tests followed a total of five years of annual topdressings on the Maury soil and four years of annual topdressings on the Decatur, Dunmore, and Dickson soils. Exchangeable potassium decreased with depth in every experiment. This agrees with the work of Munsell (17), who also found that concentration of exchangeable potassium decreased with increasing soil depth. These results do not follow the greenhouse work by Halstead, et al. (13), which indicated that exchangeable potassium values did not vary appreciably throughout a depth of 21 inches.

Since the results of this experiment show that the movement of potassium through the soil profile is slow, there is little reason to believe that a rapid loss occurs when potassium is added at these rates. Only at the higher treatments of K_2O per acre was movement of potassium from the 0-6 inch plow layer into the 6-12 inch layer detected. One could possibly infer from these data that the exchange capacity of the surface of these four soils was capable of retaining the applied potassium. This could then account for retention of potassium in the plow layer from rates of annual fertilization that have been considered excessive.

It should be pointed out that in the Dunmore soil exchangeable potassium values of the 6-12 inch layer increased as annual potassium

fertilization was increased. This particular soil is quite cherty throughout the profile, thus allowing a high rate of percolation which would then make it possible for potassium to be illuviated into the 6-12 inch layer.

The results shown by these data raise the thought that it is possible that annual topdressing of alfalfa may not be most profitable. Perhaps higher initial applications of potash mixed throughout the 0-6 inch plow layer, and fewer topdressings over a period of years, but at higher rates than are presently recommended would give alfalfa yields comparable to the yields obtained from annual topdressings at moderate rates. It also follows that there may be less rapid loss of potassium from higher but less frequent applications than has been suspected.

Phosphorus Soil Test Data

Available phosphorus soil test data indicate that available soil phosphorus is concentrated in the surface 3 inches. This concentration was found to extend to the 0-6 inch depth in the Dunmore soil and the soil phosphorus levels were higher in this soil than in the Decatur or Dickson soils. It is quite probable that this higher concentration of available phosphorus in the 3-6 inch layer is due to the fact that this particular site was located on an area that had received previous phosphate application.

These data clearly point out the fact that phosphorus from annual applications moves only slightly downward in a period of a few years. It is shown in figures 5 through 7 that the highest available phosphorus soil test values are found in the surface inch.

Soil pH Data

Soil reaction data in figures 8, 9, 10, and 11 show that there was no appreciable effect on pH value by annual applications of K_2O .

An interesting point was observed from the Decatur soil reaction data which show that pH values of the soil layers between the 3-inch and 18-inch depths were higher than those pH values of the 0-3 inch layer.

Calcium and Magnesium Soil Test Data

After examination of values for exchangeable calcium and exchangeable magnesium, it seems that the trend of the summation of these values in pounds per acre closely follows the trend in pH value. Even though neither calcium nor magnesium values closely follow trends in pH value, the summation of the two values at each sampling depth does appear to follow the trend in pH value.

Exchangeable calcium and magnesium values from the Decatur, Dunmore, and Dickson soils are similar. The exchangeable calcium and magnesium values from Maury are higher for a given pH. This may be explained by either the high phosphate content or different kinds of clay in the Maury soil.

Yield Data

A significant increase in yield at the .05 level of probability was found at the 60-pound P_2O_5 per acre treatment and the 100-pound K_2O per acre treatment on the Decatur, Dunmore, and Dickson soils. There was no phosphate variable on the Maury soil, however, significance in yield increase at the .05 level of probability was found at the 100-pound per acre K_2O treatment. This would indicate that yield of alfalfa hay on the

four soils studied is definitely affected by annual topdressings of phosphorus and potassium.

Examination of these data show that annual applications of phosphate and potash exert an effect on yield of alfalfa. Soil test data show that there was little movement of annually applied potash and phosphate over a period of years below a depth of 12-inches.

It has been considered that potash was readily lost by leaching when applied at high rates. Yield data and soil test data results of this study cause one to wonder if moderate annual phosphate and potash applications to alfalfa on these soils are necessary. Perhaps fewer phosphate and potash applications but at higher rates over the life of the alfalfa stand would suffice.

Correlation of Soil Test Values and Yield Results

Examination of correlation results show that exchangeable potassium soil test values at various depths do not explain much of the variation in yield in 1957. This is quite evident from R^2 values obtained from statistical analysis of the data from the Maury and Dickson soils.

In explanation of R^2 values of the potassium functions of the various soils, it is quite possible that the point on the yield curve at which fertilizers were applied would affect the explanation of variation in yield. It is postulated that the fertility level of the unfertilized plots of the Maury soil was at the point on the yield curve where the line broke. Since it is possible that yields were obtained from the portion of the curve that was breaking, it would follow that the

linear equation used for potassium correlations would not explain as much variation in yield as it would were the yields obtained from straight portions of the yield curve.

This postulation could then be used as an explanation as to why the Maury soil potassium equation explains such a small amount of variation in yield.

It is suggested that the low R^2 value on the Dickson soil is due to two factors. One is the relatively high contamination of alfalfa stand with crabgrass. The other is the fact that the upper surface of Dickson stays relatively dry during the growing season, thus forcing root feeding at depths where the concentration of available potassium and phosphorus is not so high as in the plow layer.

It is to be noted from the Table of r^2 values that of the percent explanation obtained, the greatest individual amount of explanation of variation in yield came from the 3-6 inch layer on all soils except Maury.

It is probable that this soil layer was the region most favorable for root activity in 1957, thus accounting for a relatively higher r^2 value for this layer than for others.

Of the percent variation in yield explained on the Maury, the 1-3 inch layer potassium soil test values gave the greatest amount of explanation.

It is concluded from results using the potassium function of yield that soil test potassium values per se explained only a slight amount of yield variation in 1957.

Correlation data from the expression of yield as a function of 0-6 inch soil test values for available phosphorus and potassium gave a greater amount of explanation of variation in yield than did the function using only potassium values.

CHAPTER VI

SUMMARY

Soil test values for the vertical distribution of exchangeable cations, available phosphorus, and pH were determined for four soil types under established alfalfa sods.

Yield data were obtained from each soil type and correlated with soil test values for exchangeable potassium.

The major results were as follows:

1. Exchangeable soil potassium from all treatments was found to be most highly concentrated in the 0-6 inch soil layer.
2. No great amount of potassium movement below a depth of six-inches was found in three of four soils studied.
3. Available phosphorus was found to be most highly concentrated in the 0-3 inch depth and one soil had appreciably more in the 3-6 inch layer than did the others.
4. Annual phosphorus fertilization had essentially no effect on available phosphorus soil test values below a depth of six inches.
5. Significance in yield at the .05 level of probability was found in each experiment at the 60 pound P_2O_5 per acre annual treatment and the 100 pound K_2O per acre annual treatment.
6. Application of K_2O resulted in no measurable effect on pH.
7. The summation of vertical soil test values for exchangeable calcium and magnesium was found to parallel the vertical soil pH values.

8. The potassium soil test values for the different soil layers was found to correlate poorly with alfalfa yield.
9. Correlation was increased by adding available phosphorus soil test data to the function.

OSWEGO, N.Y. 13127

LITERATURE CITED

LITERATURE CITED

1. Bartholomew, R. P. and Janssen, George. Luxury consumption of potassium by plants and its significance. Jour. Amer. Soc. of Agron. 21:751-65. 1929.
2. Bear, Firman, E., and Wallace, Arthur. Alfalfa - its mineral requirements and chemical composition. New Jersey Agr. Exp. Sta. Bul. 748. 1950.
3. Beeson, K. C. The mineral composition of crops with particular reference to the soils in which they were grown - a review and compilation. U.S.D.A. Misc. Pub. 369, 1941.
4. Bonner, James, and Gaston, Arthur W. Principles of plant physiology. W. H. Freeman and Company. San Francisco. pp. 46-49. 1952.
5. Bradfield, R., Peech, M., and Chandler, R. F., Jr. A study of the relation between some of the physico-chemical properties of N. Y. soils and their response to fertilization. N. Y. Agr. Exp. Sta. (Cornell) 57th. Ann. Rpt. p. 23. 1944.
6. Cowie, G. A. Potash. Edward Arnold and Co., London. 1951.
7. Crout, P. D. A short method for evaluating determinants and solving systems of linear equations with real or complex coefficients. Marchant Methods MM-182. Oakland, Calif.
8. Doll, E. C. Effect of potash fertilization on the potassium content of alfalfa. Ky. Agr. Exp. Sta. 68th. Ann. Rpt., pp. 31-32. 1955.
9. Gammon, N. Jr. Leaching of potassium salts. Fla. Agr. Exp. Sta. Ann. Rpt. pp. 131-32. 1956.
10. _____. Effect of lime on retention of potassium. Fla. Agr. Exp. Sta. Ann. Rpt. p. 131. 1956.
11. Gerwig, J. L. Potash key to alfalfa yields. N. J. Agr. Exp. Sta. N. J. Agriculture 39 (5); 15-16. 1957.
12. _____, and Ahlgren, Gilbert H. The effects of different fertility levels on yield, persistence, and chemical composition of alfalfa. Agron. Jour. 50:291-4. 1958.
13. Halstead, R. L., Nielsen, K. F., and MacLean, A. J. P and K supply for alfalfa in soils sampled at different depths. Canadian Journal of Soil Science. 37:61-70. 1957.

14. Long, O. H. Root development of farm crops in Tenn. A thesis. 1958.
15. MacGregor, J. M., Brownell, J. R., and Nelson, W. W. Phosphate-potash maintain alfalfa stand with profitable hay yield. Better Crops With Plantfood. 42:26-34. 1958.
16. Meyer, Bernard, S., and Anderson, Donald B. Plant physiology. D. Van Nostrand Company, Inc., New York. pp. 417-18. 1946.
17. Munsell, R. I. The potash fertilization of alfalfa in Connecticut. Better Crops With Plantfood. 31:13-15+. 1957.
18. Ostle, Bernard. Statistics in Research. The Iowa State College Press. Ames, Iowa, pp. 206-15. 1954.
19. Pohlman, G. G. Effect of liming on different soil layers on yield of alfalfa and on root development and nodulation. Soil Sci. 62:255-66, 1946.
20. Seay, W. A., Attoe, O. J., and Truog, E. Correlation of the potassium content of alfalfa with that available in soils. Soil Sci. Amer. Proc. 14:245-49. 1949.
21. _____, and Weeks, M. E. The effect of time of topdressing on uptake of phosphorus and potassium by an established stand of alfalfa. Soil Sci. Soc. Amer. Proc. 19:458-61, 1955.
22. Snider, H. J. Chemical composition of hay and forage crops as affected by various soil treatments. Ill. Agr. Exp. Sta. Bul. 518, 1946.
23. Stivers, Russell K., and Ohlrogge, A. J. Influence of phosphorus and potassium fertilization of two soil types on alfalfa yield stand, and content of these elements. Agron. Jour. 44:618-21. 1952.
24. Thorp, F. C., and Hobbs, J. A. Effect of lime application on nutrient uptake by alfalfa. Soil Sci. Soc. Amer. Proc. 20:544-47. 1956.
25. Tintner, Gerhard. Econometrics. John Wiley & Sons, Inc. New York. pp. 342-47. 1952.
26. Vandecaveye, S. C., and Bond, L. V. Yield and composition of alfalfa as affected by various fertilizers and soil types. Jour. of Amer. Soc. Agron. 28:491-505. 1936.
27. Woodhouse, W. W., Jr. Growing alfalfa in North Carolina. Better Crops With Plantfood. 32(7):6. 1948.



APPENDIXES

APPENDIX A

PROCEDURE FOR DETERMINATION OF EXCHANGEABLE CALCIUM AND MAGNESIUM OF SOILS

1. Place 10 grams of air-dry soil (ground to a fineness that will pass a 2 mm. sieve) in a 125 ml. erlenmeyer flask.
2. Add 50 ml. of neutral normal ammonium acetate.
3. Shake for 30 minutes and let set overnight.
4. Shake for 30 minutes the following morning.
5. Filter, using Whatman No. 42 filter paper, with suction flask and wash with an additional 50 ml. of neutral ammonium acetate, collecting entire filtrate.
6. Procure a small portion of the filtrate (about 5 ml.) and determine exchangeable calcium content with a Beckman DU flame spectrophotometer equipped with a photomultiplier attachment. A wavelength of 422.7 is used for calcium.
7. Sample readings are compared with the calibration curve obtained from standard solutions and the calcium content of the soil is calculated.
8. Samples for determining magnesium are obtained by procuring a 50 ml. aliquot of the original filtrate and taking to dryness on the hot plate.
9. Destroy organic matter with 30 per cent hydrogen peroxide.
10. Add 20 ml. of 0.1 N hydrochloric acid.
11. Procure a small portion of this solution (about 5 ml.) to determine exchangeable magnesium with a Beckman DU flame spectrophotometer equipped with a photomultiplier attachment. A

wavelength of 285.2 is used.

12. The sample readings are compared with the calibration curve obtained from standard solutions and magnesium content of the soil calculated.

APPENDIX B

PROCEDURE FOR DETERMINATION OF AVAILABLE PHOSPHORUS
AND EXCHANGEABLE POTASSIUM IN SOILS

1. Transfer 6.25 grams of air-dry soil (ground to a fineness that will pass a 2 mm. sieve) into a 125 ml. erlenmeyer flask.
2. Add small amount of activated carbon and mix.
3. Add 25 ml. of extracting solution (0.05N sulfuric acid containing 1 per cent ammonium sulfate).
4. Shake for five minutes.
5. Filter, using Whatman No. 1 filter paper, collecting entire filtrate.
6. Pipette 10 ml. of filtrate into 25 ml. erlenmeyer flask.
7. Add 0.5 ml. of molybdic acid solution and mix.
8. Add 8 drops of reducing agent (amino-naphthol-sulfonic acid) and mix immediately.
9. Read in spectrophotometer at 650 wavelength 15 minutes after adding reducing agent.
10. Convert readings to ppm. phosphorus from standard curve plotted from readings obtained from phosphorus standards run in a similar manner.
11. Use remainder of filtrate to determine potassium concentration by comparing reading obtained on a Perkin-Elmer flame photometer with those obtained using standard solutions.
12. Convert readings to ppm. potassium from standard curve plotted from readings obtained from potassium standards run in a similar manner.

APPENDIX C

PROCEDURE FOR DETERMINATION
OF pH OF SOILS

1. Place about 25 grams of air-dry soil (ground to a fineness that will pass a 2 mm. sieve) in a 50 ml. beaker.
2. Add distilled water until thin pasty mixture is obtained.
3. Allow to set until soil becomes well saturated.
4. Re-mix and place electrodes of pH meter into the soil mixture and read pH directly.

APPENDIX D

SOIL TEST VALUES FOR EXCHANGEABLE CATIONS, AVAILABLE
PHOSPHORUS, AND pH ON MAURY SILT LOAM FOLLOWING
VARIOUS ANNUAL FERTILITY TREATMENTS

Tmt. No.	Annual P ₂ O ₅ -and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
1	0-0-0	0	0	0-1	35	209			6.2
				1-3	25	104			6.2
				3-6	23	92			6.1
				6-12	31	100			6.0
				12-18	38	126			5.9
				18-24	29	128			5.7
				24-30	21	130			5.4
				30-36	20	133			5.1
2	0-0-100 applied in February	0	415	0-1	32	454			6.0
				1-3	25	215			5.9
				3-6	24	132			6.0
				6-12	32	126			5.9
				12-18	40	146			5.9
				18-24	31	140			5.7
				24-30	20	136			5.6
				30-36	19	147			5.3
3	0-0-200 applied in February	0	830	0-1	40	699	2975	230	6.0
				1-3	30	474	2450	85	5.9
				3-6	26	252	2663	115	6.0
				6-12	30	153	2775	115	6.0
				12-18	37	168	2988	170	5.9
				18-24	31	149	2913	210	5.6
				24-30	22	152	2538	245	5.4
				30-36	21	159	2375	305	5.1
4	0-0-300 applied in February	0	1245	0-1	33	948			6.2
				1-3	24	786			6.1
				3-6	24	450			6.2
				6-12	30	174			6.2
				12-18	35	178			6.1
				18-24	25	163			5.9
				24-30	17	170			5.6
				30-36	17	172			5.3

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
5	0-0-400 applied in February	0	1660	0-1	35	1280			6.0
				1-3	25	1170			6.1
				3-6	21	732			6.2
				6-12	29	235			6.2
				12-18	34	178			6.1
				18-24	26	156			5.7
				24-30	18	183			5.5
				30-36	19	201			5.1
6	0-0-100 applied after first cutting	0	415	0-1	35	144			6.0
				1-3	26	237			5.9
				3-6	24	130			5.9
				6-12	30	118			6.0
				12-18	37	143			5.8
				18-24	29	139			5.7
				24-30	21	135			5.4
				30-36	19	145			5.2
7	0-0-200 applied after first cutting	0	830	0-1	35	956	2788	220	6.0
				1-3	24	636	2338	80	5.8
				3-6	24	280	2625	50	5.8
				6-12	32	144	2638	85	5.9
				12-18	42	159	2925	155	5.8
				18-24	35	140	2988	195	5.7
				24-30	27	139	2775	215	5.5
				30-36	21	142	2625	260	5.4
8	0-0-300 applied after first cutting	0	1245	0-1	35	1118			6.0
				1-3	26	828			5.8
				3-6	23	415			5.9
				6-12	30	159			6.0
				12-18	34	178			5.8
				18-24	24	158			5.6
				24-30	19	168			5.1
				30-36	20	172			4.9
9	0-0-400 applied after first cutting	0	1660	0-1	40	1390			5.9
				1-3	28	1220			5.8
				3-6	24	700			5.8
				6-12	28	242			5.9
				12-18	37	211			5.8
				18-24	26	171			5.6
				24-30	18	165			5.3
				30-36	18	169			5.0

APPENDIX E

54

SOIL TEST VALUES FOR EXCHANGEABLE CATIONS, AVAILABLE PHOSPHORUS,
AND pH ON DECATUR SILTY CLAY LOAM FOLLOWING VARIOUS
ANNUAL FERTILITY TREATMENTS

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
1	0-0-0	0	0	0-1	6	252			6.4
				1-3	6	123			6.4
				3-6	3	91			6.7
				6-12	2	96			6.7
				12-18	2	100			6.6
				18-24	2	103			6.0
				24-30	2	120			5.1
				30-36	3	124			5.0
2	0-0-100	0	332	0-1	4	528			6.2
				1-3	4	260			6.3
				3-6	3	123			6.6
				6-12	2	105			6.7
				12-18	2	118			6.5
				18-24	2	110			6.1
				24-30	2	120			5.2
				30-36	2	122			4.7
3	0-0-200	0	664	0-1	6	701	2117	207	6.1
				1-3	6	565	2183	220	6.3
				3-6	5	236	2300	307	6.6
				6-12	3	135	2017	307	6.8
				12-18	4	129	1967	333	6.4
				18-24	2	130	1650	373	5.6
				24-30	3	131	1350	380	5.0
				30-36	3	166	1067	360	4.7
4	0-0-300	0	996	0-1	6	853			6.3
				1-3	5	683			6.4
				3-6	4	413			6.7
				6-12	3	186			6.7
				12-18	3	154			6.3
				18-24	4	163			5.5
				24-30	3	163			4.9
				30-36	2	161			4.7

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
5	0-0-400	0	1328	0-1	6	1173			6.1
				1-3	4	1067			6.2
				3-6	7	568			6.5
				6-12	2	218			6.6
				12-18	2	182			6.0
				18-24	2	174			5.7
				24-30	2	170			5.5
				30-36	2	183			5.0
6	0-60-0	104	0	0-1	23	194			6.3
				1-3	7	100			6.5
				3-6	3	83			6.8
				6-12	1	85			6.7
				12-18	3	93			6.5
				18-24	2	97			5.8
				24-30	2	106			5.1
				30-36	2	119			4.9
7	0-60-100	104	332	0-1	19	250			5.8
				1-3	7	142			6.2
				3-6	4	105			6.6
				6-12	3	103			6.5
				12-18	2	99			6.1
				18-24	2	113			5.3
				24-30	2	142			4.9
				30-36	3	165			4.9
8	0-60-200	104	664	0-1	18	454	2350	147	5.9
				1-3	7	265	2617	120	6.1
				3-6	3	134	2583	173	6.6
				6-12	2	103	2033	200	6.7
				12-18	2	102	1850	240	6.4
				18-24	3	108	1667	267	5.9
				24-30	2	120	1417	293	5.3
				30-36	2	142	1083	320	5.0
9	0-60-300	104	996	0-1	15	581			6.0
				1-3	7	477			6.3
				3-6	4	226			6.5
				6-12	3	141			6.6
				12-18	2	117			6.0
				18-24	3	136			5.2
				24-30	2	158			4.6
				30-36	3	171			4.6

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
10	0-60-400	104	1328	0-1	25	880			6.3
				1-3	5	803			6.4
				3-6	4	354			6.7
				6-12	3	150			6.6
				12-18	3	123			6.2
				18-24	3	124			5.4
				24-30	3	151			4.9
				30-36	3	150			4.6
11	0-120-0	208	0	0-1	61	183			6.0
				1-3	20	100			6.3
				3-6	5	88			6.6
				6-12	4	93			6.4
				12-18	4	102			6.2
				18-24	4	102			5.5
				24-30	3	122			5.1
				30-36	3	136			5.0
12	0-120-100	208	332	0-1	50	233			5.8
				1-3	9	121			6.2
				3-6	4	84			6.5
				6-12	2	81			6.7
				12-18	2	96			6.5
				18-24	2	102			6.1
				24-30	2	108			5.4
				30-36	2	120			5.0
13	0-120-200	208	664	0-1	63	386	2917	153	5.9
				1-3	11	244	2950	147	6.3
				3-6	5	131	2850	167	6.7
				6-12	3	107	2367	220	6.7
				12-18	3	109	2083	227	6.6
				18-24	3	115	2050	227	6.2
				24-30	3	136	1600	240	5.4
				30-36	3	155	1283	233	5.0
14	0-120-300	208	996	0-1	46	667			5.9
				1-3	9	464			6.1
				3-6	5	209			6.5
				6-12	3	140			6.6
				12-18	4	135			6.3
				18-24	4	135			5.5
				24-30	3	145			4.8
				30-36	3	171			4.6

Tmt. No.	Annual P ₂ O ₅ and K ₂ O ⁵ tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
15	0-120-400	208	1328	0-1	58	749			5.7
				1-3	12	597			6.1
				3-6	5	303			6.5
				6-12	3	155			6.7
				12-18	3	138			6.5
				18-24	3	164			5.9
				24-30	3	153			5.0
				30-36	3	168			4.8
16	0-180-0	312	0	0-1	142	161			6.2
				1-3	36	92			6.4
				3-6	7	88			6.6
				6-12	13	89			6.7
				12-18	5	93			6.5
				18-24	3	99			6.2
				24-30	3	106			5.6
				30-36	3	120			5.2
17	0-180-100	312	332	0-1	78	215			5.9
				1-3	15	113			6.5
				3-6	5	87			6.8
				6-12	4	89			6.7
				12-18	3	89			6.1
				18-24	3	96			5.7
				24-30	3	111			5.2
				30-36	3	125			4.8
18	0-180-200	312	664	0-1	116	379	2567	167	5.8
				1-3	22	253	2667	147	6.2
				3-6	5	134	2483	207	6.7
				6-12	3	106	2133	267	6.6
				12-18	5	111	1983	287	5.9
				18-24	3	114	1667	293	5.3
				24-30	3	129	1167	293	4.8
				30-36	3	148	1150	293	4.8
19	0-180-300	312	996	0-1	104	589			5.6
				1-3	23	480			6.0
				3-6	7	264			6.5
				6-12	3	142			6.5
				12-18	4	142			6.1
				18-24	3	131			5.7
				24-30	4	156			5.1
				30-36	3	165			4.8

Tmt. No.	Annual P ₂ O ₅ and K ₂ O ⁵ tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
20	0-180-400	312	1328	0-1	132	648			5.7
				1-3	43	591			5.9
				3-6	8	435			6.5
				6-12	4	215			6.6
				12-18	5	142			6.1
				18-24	3	130			5.8
				24-30	4	128			5.3
				30-36	4	138			5.2

APPENDIX F

59

SOIL TEST VALUES FOR EXCHANGEABLE CATIONS, AVAILABLE PHOSPHORUS,
AND pH ON DUMORE SILT LOAM FOLLOWING VARIOUS ANNUAL
FERTILITY TREATMENTS

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
1	0-0-0	0	0	0-1	20	178			6.6
				1-3	17	94			6.6
				3-6	11	69			6.0
				6-12	7	98			5.0
2	0-0-100	0	332	0-1	17	293			6.5
				1-3	11	187			6.5
				3-6	10	123			6.0
				6-12	4	103			5.3
3	0-0-200	0	664	0-1	13	313	1667	287	6.4
				1-3	13	269	1450	282	6.2
				3-6	9	219	1100	247	5.8
				6-12	5	158	867	173	4.9
4	0-0-300	0	996	0-1	17	380			6.2
				1-3	11	351			6.2
				3-6	8	346			6.0
				6-12	6	265			5.4
5	0-0-400	0	1328	0-1	21	412			6.5
				1-3	14	357			6.5
				3-6	12	388			6.3
				6-12	7	294			5.5
6	0-60-0	104	0	0-1	56	159			6.3
				1-3	16	72			6.4
				3-6	9	56			6.0
				6-12	6	79			5.1
7	0-60-100	104	332	0-1	56	222			6.4
				1-3	19	140			6.6
				3-6	10	85			6.2
				6-12	5	95			5.5

Tmt. No.	Annual P ₂ O ₅ and K ₂ O ⁵ tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
8	0-60-200	104	664	0-1	81	291	1800	273	6.2
				1-3	44	205	1517	287	6.1
				3-6	16	161	1200	273	5.7
				6-12	8	113	883	173	5.2
9	0-60-300	104	996	0-1	50	360			6.3
				1-3	22	316			6.3
				3-6	9	289			5.9
				6-12	5	219			5.1
10	0-60-400	104	1328	0-1	53	374			6.2
				1-3	28	322			6.2
				3-6	15	319			5.9
				6-12	10	236			5.2
11	0-120-0	208	0	0-1	106	159			6.5
				1-3	38	89			6.5
				3-6	16	72			6.2
				6-12	10	85			5.2
12	0-120-100	208	332	0-1	103	238			6.3
				1-3	39	110			6.3
				3-6	18	79			6.2
				6-12	8	84			5.6
13	0-120-200	208	664	0-1	143	277	1883	267	6.3
				1-3	59	222	1650	300	6.4
				3-6	24	172	1300	287	5.9
				6-12	10	149	1000	227	5.1
14	0-120-300	208	996	0-1	98	336			6.3
				1-3	43	279			6.3
				3-6	15	249			5.8
				6-12	8	222			5.0
15	0-120-400	208	1328	0-1	108	407			6.2
				1-3	83	307			5.9
				3-6	27	361			5.7
				6-12	11	228			5.2
16	0-180-0	312	0	0-1	169	196			6.2
				1-3	72	76			6.2
				3-6	19	59			6.0
				6-12	6	77			5.4

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Application P (Lbs./A)	Exchangeable Cations Lbs./A			pH
		P	K			K	Ca	Mg	
17	0-180-100	312	332	0-1	173	187			6.2
				1-3	88	95			6.2
				3-6	29	68			6.0
				6-12	11	85			5.2
18	0-180-200	312	664	0-1	176	306	1900	273	6.2
				1-3	93	178	1600	280	6.1
				3-6	23	129	1283	267	5.8
				6-12	9	132	983	193	5.1
19	0-180-300	312	996	0-1	200	377			6.3
				1-3	122	343			6.1
				3-6	30	318			5.6
				6-12	9	201			4.8
20	0-180-400	312	1328	0-1	203	413			6.4
				1-3	114	393			6.4
				3-6	40	437			6.2
				6-12	12	343			5.5

SOIL TEST VALUES FOR EXCHANGEABLE CATIONS, AVAILABLE PHOSPHORUS,
AND pH ON DICKSON SILT LOAM FOLLOWING VARIOUS ANNUAL
FERTILITY TREATMENTS

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
1	0-0-0	0	0	0-1	14	149			6.1
				1-3	10	50			5.8
				3-6	8	46			6.0
				6-12	5	56			5.0
				12-18	4	78			4.9
				18-24	4	64			4.8
2	0-0-100	0	332	0-1	12	244			5.8
				1-3	11	88			5.6
				3-6	10	46			6.2
				6-12	4	54			5.2
				12-18	3	82			4.8
				18-24	3	78			4.8
3	0-0-200	0	664	0-1	11	464	2000	110	6.0
				1-3	9	192	1700	70	5.8
				3-6	8	80	2575	50	6.4
				6-12	5	76	1600	120	5.0
				12-18	3	74	1275	260	4.6
				18-24	3	82	1000	390	4.8
4	0-0-300	0	996	0-1	12	680			5.8
				1-3	11	464			5.6
				3-6	9	208			6.0
				6-12	4	108			5.0
				12-18	3	86			4.6
				18-24	3	100			4.8
5	0-0-400	0	1328	0-1	13	768			6.0
				1-3	10	684			5.8
				3-6	10	400			5.9
				6-12	5	147			5.2
				12-18	4	94			4.5
				18-24	5	114			4.6

Tmt. No.	Annual P ₂ O ₅ and K ₂ O ⁵ tmt (lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
6	0-60-0	104	0	0-1	69	144			5.9
				1-3	14	44			6.1
				3-6	11	44			6.2
				6-12	6	60			5.2
				12-18	3	66			4.8
				18-24	5	60			4.8
7	0-60-100	104	332	0-1	104	190			5.5
				1-3	21	72			5.4
				3-6	11	44			6.2
				6-12	6	56			5.2
				12-18	5	74			5.7
				18-24	5	82			4.7
8	0-60-200	104	664	0-1	50	279	1600	60	5.4
				1-3	15	166	1175	30	5.2
				3-6	16	76	1650	30	5.8
				6-12	5	62	1525	80	5.0
				12-18	3	78	1150	220	4.7
				18-24	4	94	925	380	4.8
9	0-60-300	104	996	0-1	61	444			5.6
				1-3	22	304			5.3
				3-6	14	140			5.9
				6-12	5	84			5.3
				12-18	3	90			4.6
				18-24	5	108			4.7
10	0-60-400	104	1328	0-1	38	640			6.2
				1-3	13	444			5.8
				3-6	11	221			6.0
				6-12	5	122			5.0
				12-18	3	92			4.6
				18-24	5	103			4.8
11	0-120-0	208	0	0-1	157	212			6.0
				1-3	32	58			6.1
				3-6	13	46			6.2
				6-12	7	58			5.0
				12-18	4	68			4.8
				18-24	1	66			4.8
12	0-120-100	208	332	0-1	131	172			5.6
				1-3	23	58			5.6
				3-6	13	44			6.0
				6-12	6	62			5.1
				12-18	3	64			4.8
				18-24	7	66			4.9

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cations (Lbs./A)			pH
		P	K			K	Ca	Mg	
13	0-120-200	208	664	0-1	154	201	1625	100	5.4
				1-3	54	82	1275	30	5.2
				3-6	18	46	1775	30	6.0
				6-12	9	60	1875	60	5.4
				12-18	4	88	1350	280	4.7
				18-24	7	92	1025	440	4.8
14	0-120-300	208	996	0-1	121	444			5.4
				1-3	41	345			5.2
				3-6	15	182			5.5
				6-12	6	78			5.0
				12-18	5	90			4.6
				18-24	5	96			4.6
15	0-120-400	208	1328	0-1	123	588			6.0
				1-3	24	452			5.4
				3-6	14	260			5.6
				6-12	7	119			4.7
				12-18	5	110			4.6
				18-24	7	119			4.8
16	0-180-0	312	0	0-1	218	169			5.8
				1-3	86	52			6.0
				3-6	19	50			6.0
				6-12	8	64			5.0
				12-18	5	76			4.8
				18-24	6	74			4.8
17	0-180-100	312	332	0-1	199	200			5.6
				1-3	59	62			5.5
				3-6	22	48			6.0
				6-12	9	60			5.0
				12-18	3	78			4.8
				18-24	7	72			4.8
18	0-180-200	312	664	0-1	191	238	1700	80	5.4
				1-3	58	97	1575	30	5.4
				3-6	19	64	1850	30	6.0
				6-12	11	66	1700	80	5.2
				12-18	6	82	1275	220	4.7
				18-24	8	88	875	370	4.6

Tmt. No.	Annual P ₂ O ₅ and K ₂ O tmt (Lbs./A)	Total Application (Lbs./A)		Soil Depth Inches	Available P (Lbs./A)	Exchangeable Cation (Lbs./A)			pH
		P	K			K	Ca	Mg	
19	0-180-300	312	996	0-1	202	390			5.4
				1-3	67	222			5.2
				3-6	17	111			5.6
				6-12	10	84			5.0
				12-18	5	86			4.6
				18-24	8	98			5.7
20	0-180-400	312	1328	0-1	191	616			5.6
				1-3	54	398			5.5
				3-6	16	197			5.8
				6-12	12	136			4.7
				12-18	5	102			4.6
				18-24	8	102			4.6

APPENDIX H

c_{ij} Values With Ex_{ij} and Resulting Partial Regression Coefficients
 Where $\hat{Y} = f(K_{0-1}'' + K_{1-3}'' + K_{3-6}'' + K_{6-12}'')$

Decatur silty clay loam

i	j				Ex_{ij}
	1	2	3	4	
1	.000004	-.000005	.000003	-.000002	-1535.96
2	-.000005	.000009	-.000008	.000005	6.23
3	.000003	-.000008	.000017	-.000023	922.14
4	-.000002	.000005	-.000023	.000061	449.46
b_j	-.004308	.002606	.009396	.009311	

Dunmore silt loam

1	.000009	-.000006	.0000002	-.000001	1208.20
2	-.000006	.000023	-.000016	.000001	1089.50
3	.0000002	-.000016	.000019	-.000007	1353.50
4	-.000001	.000001	-.000007	.000011	631.01
b_j	.003977	-.003216	.004109	-.002652	

Dickson silt loam

1	.000014	-.000021	.000021	-.000028	835.46
2	-.000021	.000049	-.000059	.000019	943.10
3	.000021	-.000059	.000091	-.000057	570.77
4	-.000028	.000019	-.000057	.000270	165.20
b_j	-.000749	-.001869	.004426	.006596	

APPENDIX I

c_{ij} Values With Ex_{1j} and Resulting Partial Regression Coefficients Where $Y = f(K_{0-1}'' + K_{1-3}'' + K_{3-6}'' + K_{6-12}'' + K_{12-18}'' + K_{18-24}'' + K_{24-30}'' + K_{30-36}'')$

Maury silt loam

i	j								Ex_{1j}
	1	2	3	4	5	6	7	8	
1	.000002	-.000002	.00000005	.000004	-.000008	-.0000008	.000005	-.000004	1191.82
2	-.000002	.000003	-.0000002	-.000005	.000006	.000003	-.000006	.000005	2120.77
3	.00000005	-.0000002	.0000008	-.0000005	.0000005	.00000002	-.0000007	.0000002	1851.86
4	.000004	-.000005	-.0000005	.000045	-.000052	-.000011	.000004	-.000012	177.90
5	-.000008	.000006	.0000005	-.000052	.000220	-.000127	-.000072	.000040	83.49
6	-.0000008	.000003	.00000002	-.000011	-.000127	.000296	-.000036	-.000012	57.93
7	.000005	-.000006	-.0000007	.000004	.000072	-.000036	.000364	-.000202	172.86
8	-.000004	.000005	.000002	-.000012	.000040	-.000012	-.000202	.000158	116.51
b_j	-.000139	.000293	.000097	-.000444	-.000191	.000242	.002393	-.000980	

APPENDIX J

c_{1j} Values With Ex_{1y} and Resulting Partial Regression Coefficients
 Where $Y = f(P_{0-6''} + K_{0-6''} + P_{0-6''}^2 + K_{0-6''}^2 + PK_{0-6''})$

Decatur silty clay loam

i	j					Ex_{1y}
	1	2	3	4	5	
1	2201.761242	11.813913	-44.568718	.002983	-.553660	.000431
2	11.813913	8.530839	.444595	-.008494	-.095565	.000279
3	-44.568718	.444595	1.127756	-.000552	-.011122	.014736
4	.002983	-.008494	-.000552	.000009	.000067	-1.184977
5	-.553660	-.095565	-.011122	.000067	.003245	.181383
b_j	.191531	.006755	-.003830	-.000008	.000080	

Dunmore silt loam

1	369.011085	-9.212659	-2.728184	.056715	-.294938	.000417
2	-9.212659	35.978506	.142626	-.074295	-.006148	.001242
3	-2.728184	.142626	.028449	-.000369	-.000509	.052103
4	.056715	-.074295	-.000369	.000171	-.000112	.532280
5	-.294938	-.006148	-.000509	-.000112	.001372	.134434
b_j	-.009173	.007903	.000257	-.000012	-.000032	

Dickson silt loam

1	1746.840000	65.863104	-18.329791	-.038976	-1.630823	.000023
2	65.863104	37.314693	-.208671	-.052768	-.325373	.002241
3	-18.329791	-.208671	.214003	-.000123	.009988	-.001032
4	-.038976	-.052768	-.000123	.000083	.000355	1.040433
5	-1.630823	-.325373	.009988	.000355	.005525	.063285
b_j	.062934	.009859	-.000606	-.000010	-.000058	