THE EFFECT OF MAGNESIUM, BORON, AND POTASSIUM ON THE GROWTH AND CHEMICAL COMPOSITION OF RED CLOVER GROWN ON CERTAIN SOILS OF THE CLAYPAN GROUP

by

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TABLE OF CONTENTS

INTRODUCTION

Preliminary investigations have indicated a deficiency of potassium and some of the minor elements in soils of the claypan group. This fact together with the desire to obtain a greater knowledge of the properties of these soils initiated this experiment.

The practical use of potash in crop production depends to a large extent upon the potassium requirement of the specific crop and the potassium supplying power of the soil. Most root crops and legumes require large amounts of potassium for maximum growth (1). Potassium also is important in determining the quality of the crop produced (9). Red clover being a legume with a relatively high potassium requirement together with the fact that the soils of southeastern Kansas are somewhat deficient in this element presented an interesting combination for study. It was believed that the growth of this crop would result in a more rapid depletion of the soil potassium than would growing a nonlegume such as wheat.

Results reported by Smith from field experiments at 20 locations in southeastern Kansas showed the alfalfa yield was increased slightly over the no treatment plot for two cuttings where potassium was applied (21). The combination of phosphorus and potassium gave an increased mean yield of greater magnitude than the use of either element alone at the time of both cuttings. Fourteen of the 20 locations produced higher yields as a result of the phosphorus-potassium treatment at the time of the first cutting than did the use of phosphorus alone. Fifteen of the 19 locations gave a similar response at the time of the second cutting. Magnesium and boron treatments were also included in this study. Applied magnesium did not seem to be especially beneficial for either cutting of alfalfa. A beneficial effect was realized for both cuttings at only one location and this was very small.

Results reported by Myers indicate the need for potash fertilizer when the rate of phosphate fertilization is increased (12). Considerably higher yields were obtained when potassium was added in addition to phosphorus. Only slightly increased yields were obtained when potassium was added alone. Again the use of magnesium and boron did not appear to increase the yield of alfalfa appreciably. One individual field did show a response due to the added magnesium while several fields gave some indication that boron was beneficial.

Smith reported on the soil fertility investigations at the Columbus Experiment Field (22). An overall increased yield was realized from the addition of potash to corn, soybeans, wheat, and alfalfa. The magnitude of the response was greatest in the case of corn. Soybeans have responded more to potash in recent years. The response in yield of alfalfa has been rather small but consistent. Wheat and oats have not given consistent responses to potash fertilizer. Results of these experiments agreed closely with those given by Myers (12) and Smith (23) with regard to potash, magnesium, and boron responses obtained in experiments conducted on farmer fields.

In a study conducted by Hunter, Toth, and Bear dealing with calcium-potassium ratios for alfalfa, it was found that if the calcium content of the plant material became greater than 2 per cent an abrupt drop in yield resulted (10). This was accompanied by a reduction of the potassium content to below 1 per cent with a calcium-potassium ratio in the soil of about 4:1. These were considered critical limits for alfalfa.

Pierre and Bower concluded that potassium absorption by plants usually is decreased by the presence of high concentrations of other cations in solution; however, in some cases it may be increased (15). Potassium, having a higher "competitive ability" than other common cations, may affect the absorption of calcium and magnesium to a greater extent than is potassium absorption affected by the calcium or magnesium concentration. The influence of these other cations on potassium absorption by plants may be due to several different factors. Of these factors, the plant species and the ratio of other cations to potassium are probably the most important.

The fact that potassium is held in the soil in several forms is widely known and of utmost importance when considering the needs of plants for this element. It is important since the rate and amount of potassium released is related to soil productivity. It has been pointed out by many investigators that soil potassium may be held in a non-replaceable of "fixed" form and remain unavailable to plants (2, 7, 8, 27). Fixed potassium may serve as a reservior of semi-available potassium which may be converted to an available form when the available supply has been used. On the other hand potassium may be changed to this fixed form if an excess of available potassium is present and thus prevent the loss of potassium by leaching or luxury consumption by plants.

In a review of the literature dealing with magnesium in plants Zimmerman discussed the role of this element in the plant, the quantity of and need for it in plants, and the effect of other ions on magnesium adsorption by plants (29). It has been observed that magnesium comprises 2.7 per cent of the chlorophyll molecule, of which it is an essential constituent. Magnesium deficiency adversely affects chlorophyll formation and photosynthesis. Magnesium is believed to be related to phospholipid formation and the synthesis of nucleoproteins in plant cells by acting as a carrier of phosphates. Troug and coworkers have shown a direct relationship between the uptake of phosphorus and magnesium by the plant (26). It was found that increasing the supply of available magnesium increased the phosphorus content of pea seeds more than did increasing the supply of available phosphorus. Since magnesium is concentrated in the seed and fruit of plants, the theory that magnesium serves as a carrier of phosphorus is further supported.

In Zimmerman's review of unpublished data it was shown that with each successive alfalfa harvest, plant absorption of magnesium increased and that this increase coincided with decreased supplies of available potassium in the soil. Another observation indicated this effect of soil potassium on magnesium (17). It was noted that where magnesium deficiency was apparent in plants a large quantity of exchangeable potassium was present in the soil.

Prince, Zimmerman, and Bear concluded that the most important factor affecting the magnesium taken by alfalfa plants is the amount of potassium that is available for plant use (17). With several harvests of a crop like alfalfa the potassium content of the plant decreased and the magnesium content increased even when the plants were growing on a soil deficient in magnesium. It was stated that is a soil contained less than 6 per cent exchangeable magnesium on the exchange complex crops growing on that soil are likely to respond to application of this element. The ideal amount of magnesium is believed to be about 10 per cent of the total exchange capacity of the soil.

Field trials conducted in Massachusetts in 1948 clearly showed that additions of magnesium increased yields (11). The suggestion was made the equivalent of 30 to 40 pounds of magnesium oxide should be added to each ton of commercial fertilizer.

In studies conducted in Missouri it was found that magnesium and boron were important to the quality as well as quantity of the crops produced (18).

The conclusion was made that the external symptoms of boron toxicity at high boron levels and deficiency symptoms at low boron levels are progressively accentuated with increasing potassium concentrations in the soil (19).

Smith found no correlation between the amount of water soluble boron in the soil and yield response of alfalfa (24). Application of boron to the soil did increase the boron content of the plant tissue. No increase in yield was obtained as a result of boron treatments at any of 20 locations for the first cutting. A favorable result with respect to the borax application was noted at 9 of the 19 locations for the second cutting.

The need of the soils of Wisconsin for boron was discussed by Berger and Troug (3). About 60 per cent of the fields of alfalfa in southern Wisconsin showed symptoms of boron deficiency at the time of the second cutting. This deficiency reduced yields one-half in some cases. In second crop alfalfa hay the yield was increased from 1000 to 3000 pounds as a result of adding borax in one experiment. It was pointed out that soils should contain about 1.5 pounds, or more, of available boron per acre plow layer.

It was hoped that in this green house study some fundamental facts and relationships would be observed that would be of practical value in promoting better, higher yielding crops on the soils of the area.

The first consideration was given to the effect of potassium, boron, and magnesium on the yields of the red clover. The effects of these elements on the chemical content of the plant tissue as related to the yields and chemical composition of the soils were also studied. It was desired to bring out any relationship existing between these elements.

Two soils were selected so the effect of previously applied potash in the field could be observed on the yield of red clover. It was hoped that from the data assembled some information might be gained relative to the ability of the soils to supply plants with potassium from forms not readily available. A greenhouse study seemed the most logical way to speed up the preliminary investigations.

MATERIALS AND METHODS

Cultural Methods

Representative soils from the claypan region of Southeastern Kansas were selected in October, 1949. The six soils were taken from four locations and represented four soil types. The material designated as Soil I was obtained from a Cherokee subsoil. It was classified as a clay loam. This material was taken from a roadbank about 3 miles west and 2 miles north of Columbus, Kansas. The sample was taken from a depth of 18-36 inches. The color of the soil was yellow with gray mottling. Native grasses were growing along the bank and sorghum was growing in the field across the fence.

The material designated as Soil II was taken from an alfalfa field on the farm of Earl Dauron about 7 miles west of Girard, Kansas. This material was a Summit silty clay loam and was sampled from a depth of 0-6 inches.

Soils III and IV belong to the Parsons silt loam type and were taken from the Thayer experiment field. Alfalfa was growing on both plots but previous fertilizer applications had been different. Soil III had been treated previously with phosphorus and potassium while Soil IV had received only phosphorus. This fact presented an opportunity to observe differences due to the residual effects of potash fertilizers.

The Columbus experimental field, located 3 miles west and 4 miles north of Columbus, afforded the site from which the Cherokee silt loam material was obtained. Soybeans were growing on the plots when the samples were taken. Soil V had been treated with lime and superphosphate. Soil VI had received potash in addition to lime and superphosphate.

The soil material was spread out in the greenhouse at Kansas State College and allowed to dry. It was then passed through a 1/4 inch mesh hardware cloth and mixed.

One-half gallon glazed earthenware jars were used in this study. Two thousand grams of soil material were weighed into each jar. The chemicals used to supply the nutrient elements were mixed with the soil by placing the soil on heavy paper and tabling 25 to 30 times.

After returning the soil to the jar 500 ml of distilled water were supplied to each jar. A seed bed was prepared and the red clover seeds were planted in excess in a ring in each jar when the soil was sufficiently dry. The plants were later thinned to 20 plants per jar. The seeds were inoculated with bacteria belonging to the group *Rhizobium trifolii* which were obtained from the Department of Bacteriology. Distilled water was used in order to reduce the error caused by adding nutrients in question. No attempt was made to control the photoperiod. The jars were rearranged periodically in order to minimize the effect of differential lighting. Four crops of clover were harvested between the dates of March 12 and June 22, 1950. It was necessary to spray with parathion about every 10 days or 2 weeks in order to control red spider.

This experiment was established as one of complete factoral design according to Snedecor (25), so all possible combinations of the variable elements--potassium, boron, and magnesium--were employed. This made a total of 8 different treatments for each soil. Duplicating each treatment for six soils made a total of 96 jars.

In order to assure a sufficient supply of the elements nitrogen and phosphorus, uniform treatments of chemicals containing these elements were made. Ammonium nitrate was supplied at the rate of 400 pounds per acre. Mono-calcium phosphate was supplied at the rate of 1000 pounds per acre. Inasmuch as the subsoil material was extremely acid it seemed advisable to lime this soil. Calcium carbonate was applied to this soil at the rate of 4000 pounds per acre. The variable elements were applied at one level throughout the experiment so the rate of application would not be a factor. The materials and amounts are listed in Table 1.

Table 1. Schedule of amounts of chemicals used for various treatments.

Soil treatment	Kinds and amounts of chemical compound added					
	KCl		$Na_2B_4O_7$		$MgCl_2 \cdot 6H_2O$	
	Gms/culture	Lbs/A	Gms/culture	Lbs/A	Gms/culture	Lbs/A
No	----	----	----	---	----	----
K	1.00	1000	----	---	----	----
B	----	----	0.04	40	----	----
Mg	----	----	----	---	1.00	1000
KB	1.00	1000	0.04	40	----	----
KMg	1.00	1000	----	---	1.00	1000
BMg	----	----	0.04	40	1.00	1000
KBMg	1.00	1000	0.04	40	1.00	1000

Chemical Analyses of Plant Material

Each sample of red clover was analyzed for potassium, phosphorus, and magnesium. The plant material from the first three cuttings was analyzed for boron.

The plant material was prepared for measurement of potassium, phosphorus, and magnesium by the wet digestion method described by Piper (16). The extract was made to a volume of 100 ml. A 5 ml aliquot was taken and made to a volume of 100 ml for determining the phosphorus and potassium. Phosphorus was determined by a photometric procedure using Bray's sulfonic acid reduction method and the Coleman Jr. Spectrophotometer (6). Potassium was determined by taking a 20 ml aliquot of the phosphorus-potassium solution, adding 2 ml of Li NO_3(1100 ppm Li), and using the Perkin-Elmer flame photometer. A standard solution containing 50 ppm potassium and 100 ppm lithium as $LiNO_3$, the internal standard, was used to calibrate the instrument. The concentrations of potassium and phosphorus in the solution were determined by reference to the proper standardization curves.

The remaining 95 ml of the digest were evaporated almost to dryness on the steam plate to reduce the volume and to concentrate the magnesium. This was made to a volume of 25 ml containing 25 ppm lithium and then filtered. The clear solution was used for the determination of magnesium with the Perkin-Elmer flame photometer.

A standardizing solution containing 3000 ppm magnesium as $Mg(NO_3)_2$ and 25 ppm lithium as $LiNO_3$ was used to calibrate the photometer. An attempt was made to determine the effect of calcium, potassium and sodium on the magnesium readings when these elements were present in the solution in approximately the same concentrations as could be expected in red clover. When potassium was added to the solution the internal standard

Table 2. Effect of sodium, potassium, and calcium ions on the magnesium reading with the flame photometer.

Sample	Reading of flame photometer with indicated concentrations of cations			
	Mg 1000	Mg,Ca-1000 K-4000 Na-1500	Mg,Ca-1000 K-4000	Mg-1000 K-4000
	ppm	ppm	ppm	ppm
1	29	30	25	25
2	29	30	25	25
3	30	32	25	25
4	30	31	26	25

dial reading was less than when the solution contained magnesium alone. When sodium was added the reading was greater than the magnesium reading. The influence of calcium was less than that of either sodium or potassium. The effect was slightly additive. When potassium, sodium, calcium and magnesium were in the solution together the net result seemed to be a slightly higher reading than that for magnesium alone. It seems logical to conclude from the data in Table 2 that while this method is not strictly quantitative it is relative. Error introduced by variation in the sodium content of the plants seemed to be of greatest significance.

Boron determinations were made by the method outlined by Berger and Troug (4) and modified by Olson (13). This colorimetric method gave an estimate of boron based on the color change produced when boron was added to an acid solution containing quinalizarin. The intensity of color was measured by a Coleman Universal Spectophotometer. Reference was made to a standard curve to convert readings to concentrations in the solution.

Analyses of Soil Materials

The soil materials were analyzed before and after growing the four crops of red clover.

The pH of the soils was determined with a Leeds-Northrup glass electrode. Ten ml of distilled water were added to a 10 gm sample of soil material. The mixture was stirred and allowed to stand for 30 minutes and then stirred again. A lime requirement determination, using Woodruff's buffer solution, was made on each sample having a pH value below 6.10 (28). Twenty ml of the buffer solution were added to each of these samples and after a 30 minute period the lime requirement reading was made.

Four phosphorus determinations were made on the original soil materials and a determination was made of total available phosporus on the soils after the last clover harvest. The four determinations consisted of the adsorbed phosphorus - 1:10 and 1:50 extraction ratios and total available phosphorus - 1:10 and 1:50 extraction ratios. The phosphorus was determined colorimetrically by Bray's sulfonic acid reduction method (6). The Coleman Jr. Spectrophotometer was used to measure the intensity of the blue color produced.

Exchangeable potassium, sodium, and calcium was determined by passing the cation extract through the Perkin-Elmer flame photometer. The cations were extracted under suction with Buchner funnels and suction flask with 1 N neutral ammonium acetate. This extract was made to a volume of 100 ml in a volumetric flask. $LiNO_3$ was added to bring the lithium concentration of the solution to 100 ppm.

Magnesium in the soils was determined volumetrically by the method outlined by Peech et al (14).

The boron determinations were made by the modified quinalizarin method of Berger and Troug using the Coleman Universal Spectrophotometer to measure the intensity of the color developed (13).

A mechanical analysis was made by the Bouyoucos hydrometer method (5).

The cation exchange capacity of the soils was determined by the method using the flame photometer as outlined by Rendig (20).

EXPERIMENTAL RESULTS

Illustrations

The photographs presented on the following plates were made on March 11, 1950, one day before the first harvest of the red clover. Photographs of the clover growing on various cultures of Soils I through V are shown on Plates I through V. Photographs for Soil VI were not made since there was no visual difference between the red clover growing on it and Soil V.

EXPLANATION OF PLATE I

Fig. 1. Red clover growing on the Cherokee subsoil. Treatments were as follows:

A. 1-No treatment
   2-Potassium
   3-Boron
   4-Magnesium

Fig. 2. Red clover growing on the Cherokee subsoil. Treatments are as follows:

A. 5-Potassium and Boron
   6-Potassium and Magnesium
   7-Boron and Magnesium
   8-Potassium, Boron and Magnesium

PLATE I

Fig. 1.

Fig. 2.

EXPLANATION OF PLATE II

Fig. 1. Red clover growing on the Cherokee subsoil. Treatments were as follows:

B. 1-No treatment
2-Potassium
3-Boron
4-Magnesium

Fig. 2. Red clover growing on the Cherokee subsoil. Treatments were as follows:

B. 5-Potassium and Boron
6-Potassium and Magnesium
7-Boron and Magnesium
8-Potassium, Boron and Magnesium

PLATE II

Fig. 1.

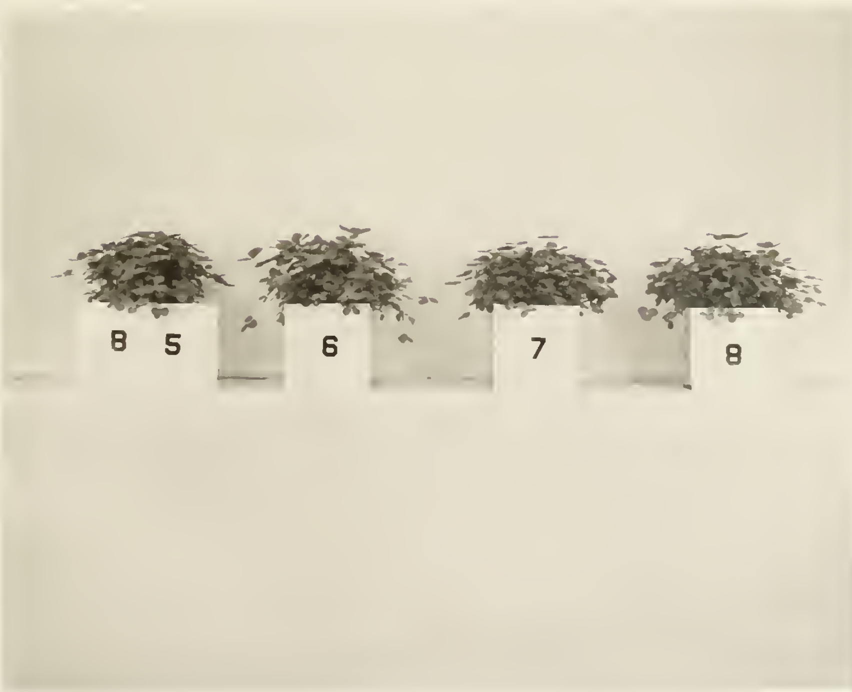

Fig. 2.

EXPLANATION OF PLATE III

Fig. 1. Red clover growing on the Cherokee subsoil.
Treatments were as follows:
C. 1-No treatment
2-Potassium
3-Boron
4-Magnesium

Fig. 2. Red clover growing on the Cherokee subsoil.
Treatments were as follows:
C. 5-Potassium and Boron
6-Potassium and Magnesium
7-Boron and Magnesium
8-Potassium, Boron and Magnesium

PLATE III

Fig. 1.

Fig. 2.

EXPLANATION OF PLATE IV

Fig. 1. Red clover growing on the Cherokee subsoil. Treatments were as follows:

D. 1-No treatment
   2-Potassium
   3-Boron
   4-Magnesium

Fig. 2. Red clover growing on the Cherokee subsoil. Treatments were as follows:

D. 5-Potassium and Boron
   6-Potassium and Magnesium
   7-Boron and Magnesium
   8-Potassium, Boron and Magnesium

PLATE IV

Fig. 1.

Fig. 2.

EXPLANATION OF PLATE V

Fig. 1. Red Clover growing on the Cherokee subsoil. Treatments were as follows:
E. 1-No treatment
2-Potassium
3-Boron
4-Magnesium

Fig. 2. Red clover growing on the Cherokee subsoil. Treatments were as follows:
E. 5-Potassium and Boron
6-Potassium and Magnesium
7-Boron and Magnesium
8-Potassium, Boron and Magnesium

PLATE V

Fig. 1.

Fig. 2.

Yield Data

The yield data for the entire experiment are summarized in Tables 3 to 43, inclusive. The data for individual soils, by cuttings, represent a mean of duplicate values. Total yields are given, by treatment, on the basis of weight of plant material per culture. This total yield also represents a mean of duplicate cultures. Finally, yields are summarized, by cuttings, all soils consolidated.

A statistical analysis is provided for each table of yield data. Inasmuch as the experiment involved a factorial design, each analysis of variance, where a significant effect of treatments was indicated, is broken down to illustrate the effect of each element or the effect of interaction of each combination of elements. An analysis of variance is provided for each individual group of yield data.

Cherokee Subsoil (I). A study of the yield data contained in Table 3 and the analyses of variance reported in Tables 4 to 8, inclusive indicated that several chemical treatments had significant effects on yield of red clover.

The yield data for the first harvest of plant material on this soil indicated there was less growth on these cultures than on the other soil materials. There were not any large differences in yield between treatments. The analysis of variance for these data indicated that chemical

Table 3. Effect of chemical treatment on mean yield of red clover, Cherokee subsoil (I).

Treatment	Yield by cutting, gms per culture: 1st	2nd	3rd	4th	Total
No	5.77	9.94	4.35	2.81	22.86
K	5.98	12.06	5.80	2.99	26.82
B	5.06	10.35	5.97	3.15	24.53
Mg	5.45	10.08	5.83	3.44	24.79
KB	6.02	13.60	8.01	4.72	32.35
KMg	3.99	9.36	5.12	3.09	21.55
BMg	5.62	9.46	7.09	3.13	25.29
KBMg	5.90	13.21	9.67	4.99	33.77
Significance of treatment effect	N.S.	**	**	**	**

** Significant at .01 level[1]
* Significant at .05 level[1]

Table 4. Analysis of variance for red clover yield data, Soil I, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	10.1230	
Between replications	1	0.0716	0.0716
Between treatments	7	6.4333	0.9190
Error	7	3.6181	0.5169

[1]On succeeding tables the forgoing notations will have the same meaning but will not be stated again.

Table 5. Analysis of variance for red clover yield data, Soil I, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	43.6036	
Between replications	1	0.4354	0.4354
Between treatments	7	40.5244	5.7892**
K	1	17.63**	
B	1	6.76**	
KB	1	7.87**	
Mg	1	3.71*	
KMg	1	1.37	
BMg	1	0.41	
KBMg	1	2.77*	
Error	7	2.6438	0.3777

Table 6. Analysis of variance for red clover yield data, Soil I, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	42.3145	
Between replications	1	0.0115	0.0115
Between treatments	7	40.8819	5.8403**
K	1	7.19**	
B	1	23.23**	
KB	1	3.78**	
Mg	1	3.21**	
KMg	1	0.65	
BMg	1	0.98*	
KBMg	1	1.84*	
Error	7	1.4211	0.2030

Table 7. Analysis of variance for red clover yield data, Soil I, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	11.0514	
Between replications	1	0.0742	0.0742
Between treatments	7	9.7151	1.3879**
K	1	2.66**	
B	1	3.33**	
KB	1	3.23**	
Mg	1	0.24	
KMg	1	0.02	
BMg	1	0.06	
KBMg	1	0.17	
Error	7	1.2621	0.1803

Table 8. Analysis of variance for combined yield data, Soil I.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	63	588.5058	
Between replications	4	0.5927	0.1482
Between treatments	7	66.6093	9.5156**
K	1	34.53**	
B	1	24.79**	
KB	1	5.18**	
Mg	1	0.08	
KMg	1	0.00	
BMg	1	1.91*	
KBMg	1	0.12	
Between cuttings	3	481.4133	160.4711**
Treatments x cuttings	21	30.9453	1.4736**
Error	28	8.9452	0.3194

treatment of the soil had no significant influence on yields for this cutting.

Plant growth was considerably greater at the time of the second cutting than at the first cutting. There were larger differences in yield between treatments and the analysis of variance for these particular data indicated a highly significant effect for treatments. The breakdown into individual effects indicated that potassium alone and boron alone had highly significant influences insofar as increasing the yield of red clover was concerned. Magnesium, when used alone, had a significant effect on red clover yields. There was a highly significant interaction between potassium and boron and a significant interaction between the three elements, potassium, boron, and magnesium.

A small yield of plant material was obtained for the third cutting than for the second. However, there was a highly significant effect indicated for treatments. A breakdown of individual effects indicated that potassium, boron and magnesium, each when used alone had a highly significant effect. There was a highly significant effect from the interaction of potassium and boron, and a significant effect from the interaction of boron and magnesium and the interaction of potassium, boron and magnesium. Only the interaction of potassium and magnesium failed to be significant. All effects were to increase the yield of red clover.

Small yields of clover were obtained for the final harvest from this soil material. A highly significant effect of treatments was indicated by the analysis of variance. Additionally, it was indicated that potassium alone, boron alone, and the interaction of potassium with boron all gave highly significant yield increases. No other element or interaction of elements indicated significance.

Finally, yield data were composited for all harvests and analysis of variance was used to gain some indication of the effects of chemical treatments on total yields of plant material for this particular soil material. The effect of treatments was indicated to be highly significant. Specifically, potassium, boron, and the interaction of potassium and boron all produced effects which were indicated to be highly significant. The interaction of boron and magnesium was significant, also.

It was interesting to note that there was a highly significant variation among cuttings and a highly significant interaction between treatments and cuttings.

Summit Silty Clay Loam (II). A study of the yield data of Table 9 and of the analysis of variance reported in Tables 10 to 14, inclusive indicated that some of the chemical treatments resulted in significant effects on the yields from Soil II.

The yields at the time of the first harvest were smaller than those obtained for the second harvest. The differences in yield between treatments were small. The analysis of variance for the data indicated that chemical treatment of the soil

Table 9. Effect of chemical treatment on mean yield of red clover, Summit silty clay loam (II).

Treatment	Yield by cutting-gms per culture 1st	2nd	3rd	4th	Total
No	5.77	9.90	6.53	2.38	24.58
K	6.35	10.63	8.41	3.43	28.82
B	6.41	11.17	6.97	2.35	26.90
Mg	6.59	11.18	8.08	3.07	28.92
KB	7.36	14.13	9.81	4.35	35.65
KMg	6.78	12.38	8.68	4.19	32.03
BMg	6.29	11.16	7.68	3.00	28.13
KBMg	8.08	15.15	11.14	5.42	39.79
Significance of treatment affect	N.S.	N.S.	**	**	**

Table 10. Analysis of variance for red clover yield data, Soil II, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	12.1534	
Between replications	1	.2916	.2916
Between treatments	7	7.1968	1.0281
Error	7	4.6650	.6664

Table 11. Analysis of variance for red clover yield data, Soil II, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	60.2040	
Between replications	1	.4489	.4989
Between treatments	7	45.9080	6.5583
Error	7	13.8471	1.9782

Table 12. Analysis of variance for red clover yield data, Soil II, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	35.8932	
Between replications	1	.5929	.5929
Between treatments	7	31.4490	4.4927**
K	1	19.23**	
B	1	3.82*	
KB	1	3.65*	
Mg	1	3.72*	
KMg	1	.11	
BMg	1	.01	
KBMg	1	.90	
Error	7	3.8513	

Table 13. Analysis of variance for red clover yield data, Soil II, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	17.9541	
Between replications	1	.2889	.2889
Between treatments	7	15.7771	2.2539**
K	1	10.83**	
B	1	1.07	
KB	1	1.26	
Mg	1	2.50*	
KMg	1	.06	
BMg	1	.02	
KBMg	1	.03	
Error	7	1.8881	.2697

Table 14. Analysis of variance for combined yield data, Soil II.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	63	711.0123	
Between replications	4	1.4076	.3519
Between treatments	7	78.9870	11.2839**
K	1	37.20**	
B	1	19.68**	
KB	1	13.00**	
Mg	1	7.21**	
KMg	1	.07	
BMg	1	.54	
KBMg	1	1.28	
Between cuttings	3	591.7103	197.2368**
Treatments x cuttings	21	15.2819	.7277
Error	28	23.6255	.8438

had no significant effect on yields for this cutting.

The yield data for the second harvest show that the amount of plant material produced was considerably greated than for the first cutting. The magnitude of treatment differences was not significant as may be noted from the analysis of variance in Table 11.

Less plant material was produced on this soil at the time of the third harvest than for the second. There was a highly significant effect observed as a result of the chemical treatments. When a breakdown of the individual effects was made, it was indicated that potassium used alone gave a highly significant response. The effect of boron, magnesium and the interaction between boron and potassium was significant. All effects were to increase yields. The smallest yield of red clover was produced at the time of the fourth harvest. The analysis of variance indicated a highly significant effect due to treatments. A breakdown of these treatments indicated that potassium alone gave a highly significant increase in yields. The effect of magnesium used alone was significant. No significant decrease was noted.

From the analysis of variance of the composite of yield data for all harvests, a highly significant effect was noted. Specifically, the effect of potassium, boron, magnesium, and the interaction of potassium and boron was indicated to be highly significant. All effects were to increase the yields. A highly significant variation occurred among cuttings.

Parsons Silt Loam (III). From a study of the yield data

Table 15. Effect of chemical treatment on mean yield of red clover, Parsons silt loam (III).

Treatment	Yield by cutting-gms per culture: 1st	2nd	3rd	4th	Total
No	10.68	9.97	4.35	2.63	27.63
K	11.24	14.94	8.96	4.62	39.76
B	9,55	8.88	4.28	3.67	26.38
Mg	9.00	8.64	4.89	3.64	26.17
KB	11.24	13.67	9.31	5.05	39.27
KMg	10.55	13.68	8.57	4.67	37.47
BMg	9.35	8.00	5.00	3.29	25.64
KBMg	11.19	13.79	9.44	4.40	38.82
Significance of treatment affect	**	**	N.S.	N.S.	**

Table 16. Analysis of variance for red clover yield data, Soil III, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	13.8084	
Between replications	1	.8789	.8789*
Between treatments	7	11.8411	1.6916**
K	1	7.96**	
B	1	1.11*(decrease)	
KB	1	.51	
Mg	1	1.71*(decrease)	
KMg	1	.33	
BMg	1	.04	
KBMg	1	.18	
Error	7	1.0884	.1555

Table 17. Analysis of variance for red clover yield data, Soil III, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	140.9700	
Between replications	1	8.2226	8.2226
Between treatments	7	112.2397	16.0342**
K	1	105.92**	
B	1	2.08	
KB	1	.08	
Mg	1	2.82	
KMg	1	.28	
BMg	1	..83	
KBMg	1	.22	
Error	7	20.5077	

Table 18. Analysis of variance for red clover yield data, Soil III, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	103.8944	
Between replications	1	.3511	.3511
Between treatments	7	80.6295	11.5185
Error	7	22.9138	3.2734

Table 19. Analysis of variance for red clover yield data, Soil III, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	12.9056	
Between replications	1	.7700	.7700
Between treatments	7	9.4584	1.3512
Error	7	2.6772	.3825

Table 20. Analysis of variance for combined yield data, Soil III.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	63	825.9226	
Between replications	4	10.2227	2.5557
Between treatments	7	155.7970	22.2567**
K	1	153.26**	
B	1	.05	
KB	1	.44	
Mg	1	1.53	
KMg	1	.02	
BMg	1	.41	
KBMg	1	.08	
Between cuttings	3	554.3433	184.7811**
Treatments x cuttings	21	58.3717	2.7796
Error	28	47.1880	1.6853

presented in Table 15 and the analysis of variance data in Tables 16 to 20, inclusive it may be observed that there were significant variations due to chemical treatment of Soil III.

The amount of the plant material produced at the time of the first harvest was greater than from Soils I or II. Considerable variation was apparant as a result of the chemicals added to the soil. This variation between treatments was indicated to be highly significant. The potassium treatment resulted in a highly significant increase in yields whereas application of boron and magnesium alone effected a significant decrease in yields of red clover.

A larger yield of red clover at the time of the second harvest was obtained for this soil. The analysis of variance indicated a highly significant effect of treatments for this harvest. A highly significant increase in yield was noted as a result of the use of potassium alone.

Yields were smaller from the third harvest of clover from this soil. A considerable amount of variation was noted among the mean yields. However, the analysis of variance showed no significant differences due to treatments. It is interesting to note that the error was large.

Small yields of clover were obtained from this soil at the time of the fourth harvest. Little variation appears due to treatments. The latter observation was substantiated by the analysis of variance data where no significant effects were indicated.

A highly significant effect due to treatments was shown in

Table 20 for the composited yields of the four cuttings. A highly significant effect resulted when potassium was used alone. This increase in yields due to potassium has been observed for all soils thus far discussed. The highly significant variation between cuttings was interesting. The fact that this soil did not respond to potassium on the third and fourth harvests may be related to the previous application of potassium to this soil in the field.

Parsons Silt Loam (IV). The fact that Soil IV was a responsive soil was clearly shown by Table 21.

There was no significant effect of treatments at t he time of the first harvest. It was interesting to note that the error was rather high thus voiding any significance.

Treatment variation was highly significant for the second harvest as may be observed from the analysis of variance data in Table 23. A highly significant increase in yields due to applications of potassium and boron was indicated.

The yields for the third harvest were lower than for the first or second harvest. A highly significant increase in yields was indicated for potassium. No other significant effect was noted for this harvest.

The lowest yields were obtained again from the fourth harvest. The differences between yields appear rather large and the analysis of variance indicated a highly significant increase in yields due to the use of potassium.

The analysis of variance for the combined yields of clover from this soil indicated a highly significant increase due to

Table 21. Effect of chemical treatment on mean yield of red clover, Parsons silt loam (IV).

Treatment	Yield by cutting-gms per culture 1st	2nd	3rd	4th	Total
No	9.32	8.54	6.24	3.24	27.34
K	11.62	15.41	12.02	5.17	44.22
B	9.82	10.41	6.14	3.59	29.96
Mg	8.78	9.48	5.93	3.27	27.46
KB	14.53	15.94	9.64	5.06	45.17
KMg	11.63	16.35	10.51	5.10	43.59
BMg	9.08	9.51	4.80	2.69	26.08
KBMg	10.56	16.63	10.71	5.79	43.69
Significance of treatment affect	N.S.	**	**	**	**

Table 22. Analysis of variance for red clover yield data, Soil IV, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	80.4520	
Between replications	1	4.8394	4.8394
Between treatments	7	50.7936	7.2562
Error	7	24.8190	3.5456

Table 23. Analysis of variance for red clover yield data, Soil IV, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	206.9636	
Between replications	1	25.5890	25.5890**
Between treatments	7	179.3679	25.6240**
K	1	174.00**	
B	1	1.83**	
KB	1	1.00	
Mg	1	.70	
KMg	1	.63	
BMg	1	1.11	
KBMg	1	.09	
Error	7	2.0067	.2867

Table 24. Analysis of variance for red clover yield data, Soil IV, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	111.7428	
Between replications	1	.3691	.3691
Between treatments	7	106.2227	15.1747**
K	1	97.80**	
B	1	2.85	
KB	1	1.53	
Mg	1	1.09	
KMg	1	.36	
BMg	1	.59	
KBMg	1	3.00	
Error	7	5.1510	

Table 25. Analysis of variance for red clover yield data, Soil IV, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	20.7181	
Between replications	1	.6006	.6006
Between treatments	7	18.8726	2.6961**
K	1	17.35**	
B	1	.03	
KB	1	.16	
Mg	1	.01	
KMg	1	.52	
BMg	1	.01	
KBMg	1	.73	
Error	7	1.2449	.1778

Table 26. Analysis of variance for combined yield data, Soil IV.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	63	1065.0321	
Between replications	4	31.3981	7.8495**
Between treatments	7	275.6939	39.3848**
K	1	270.70**	
B	1	.32	
KB	1	.23	
Mg	1	2.17	
KMg	1	.16	
BMg	1	1.49	
KBMg	1	.62	
Between cuttings	3	645.1556	215.0518**
Treatments x cuttings	21	79.5638	3.7888**
Error	28	33.2207	1.1865

the potassium application. The magnitude of this increase was even greater than that for the Parsons silt loam receiving potassium in the field. A highly significant variation was detected between replications and among cuttings. The interaction of treatments and cuttings was highly significant. The highly significant variation between replications presents some indications why the first harvest did not show significant differences due to treatments. The yield data indicate that more total clover was produced on this soil than on any of the other soils studied.

Cherokee Silt Loam (V). From the yield data of Table 27 little difference may be observed in yields of the first two harvests. The amount of plant material produced on these cultures for the first harvest was less than for the second harvest. The data contained in Tables 28 and 29 revealed that there were no significant effects due to the treatments.

At the time of the third harvest more variation may be observed from a study of the yield data in Table 27. A highly significant effect due to treatments was noted. A further study of the analysis of variance showed a highly significant increase in yields due to the addition of potassium.

Yields were smaller for the fourth harvest. The variation was not significant as indicated by the analysis of variance. The data in Table 31 showed a significant variation between replicates which probably eliminated the significance due to treatments.

Finally, by compositing the data for all harvests from

Soil V and making a study of the data in Table 32 a highly significant effect of potassium applied to these cultures was detected. Indications were that a highly significant variation among cuttings prevailed.

Cherokee Silt Loam (VI). By observing the yield data and making a study of the analysis of variance data indications of response were noted for some cuttings on this soil.

Yields on this soil at the time of the first cutting were more dependent upon treatment than was true for Soil V. A significant effect as a result of chemical treatments was indicated. This effect was a function of the significant increase in yields due to potassium and to the significant decrease in yields due to magnesium. No other significant effect was observed in Table 34 as a result of treatments.

The second harvest produced larger yields than did the first harvest. The analysis of variance showed that potassium used alone gave a highly significant increase in yields.

Data in Table 33 for the third harvest show smaller differences in yields resulting from the various chemical treatments. The analysis of variance table contains data which indicated that the effects of chemical treatments were not significant. The error was relatively high thus reducing the chances for significance.

Lower yields at the time of the fourth harvest were obtained for this soil. These lower yields reflected the influence of the extremely high temperature in the greenhouse at that time of the year and possibly the decreased supply of

Table 27. Effect of chemical treatment on mean yield of red clover, Cherokee silt loam (V).

Treatment	Yield by cutting-gms per culture				
	1st	2nd	3rd	4th	Total
No	8.23	11.81	7.82	3.07	30.93
K	10.31	12.16	10.19	5.16	37.82
B	8.35	10.33	6.89	3.25	28.82
Mg	8.56	11.67	7.81	4.51	32.55
KB	9.62	12.77	9.92	6.01	38.32
KMg	8.95	11.96	10.32	6.12	37.35
BMg	8.93	10.83	7.33	3.97	31.06
KBMg	8.08	11.07	9.45	5.56	34.16
Significance of treatment affect	N.S.	N.S.	**	N.S.	**

Table 28. Analysis of variance for red clover yield data, Soil V, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	17.6039	
Between replications	1	.5370	.5370
Between treatments	7	8.1081	1.1583
Error	7	8.9588	1.2798

Table 29. Analysis of variance for red clover yield data, Soil V, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	19.6235	
Between replications	1	1.6320	1.6320
Between treatments	7	8.6764	1.2395
Error	7	9.3151	1.3307

Table 30. Analysis of variance for red clover yield data, Soil V, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	29.8584	
Between replications	1	.0400	.0400
Between treatments	7	27.1254	3.8751**
K	1	25.02*	
B	1	1.63	
KB	1	.02	
Mg	1	.01	
KMg	1	.15	
BMg	1	.01	
KBMg	1	.28	
Error	7	2.6930	.3847

Table 31. Analysis of variance for red clover yield data, Soil V, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	28.9041	
Between replications	1	4.1310	4.1310*
Between treatments	7	19.0399	2.7200
Error	7	5.7332	.8190

Table 32. Analysis of variance for combined data, Soil V.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	63	480.7041	
Between replications	4	6.3400	1.5850
Between treatments	7	45.5848	6.5121**
K	1	36.77**	
B	1	2.47	
KB	1	.05	
Mg	1	.04	
KMg	1	4.50	
BMg	1	.59	
KBMg	1	1.16	
Between cuttings	3	384.7147	128.2382**
Treatments x cuttings	21	18.3644	.8745
Error	28	25.7002	.9179

plant nutrients. Although these yields were lower a significant effect due to chemical treatments may be observed from the analysis of variance. In breaking down this effect it was indicated from Table 37 that the influence of potassium was highly significant.

In a final analysis of the combined yield data for this soil a highly significant influence was indicated for treatments. A highly significant effect was indicated for the addition of potassium alone. As was observed on the other soils the variation among cuttings was highly significant according to the data in Table 38.

First Cutting. A consideration was given to the influence from all soils for each cutting. A study of the data in Table 39 and in the analysis of variance, Table 40, indicated the highly significant influence of treatments. Breaking this down into the individual effects, the observation was made that potassium effected a highly significant increase in yield. The other element which produced a highly significant effect was magnesium. Indications were that its effect resulted in lower yields for the first cutting. A fact of importance was the highly significant variation among soils.

Second Cutting. The mean yields were largest for the second cutting probably as a result of the longest growing period allowed. Highly significant effects resulted from the treatments as was indicated in Table 41. A significant interaction between potassium and boron was indicated as was the highly significant effect of potassium alone. It is im-

Table 33. Effect of chemical treatment on mean yield of red clover, Cherokee silt loam (VI).

Treatment	Yield by cutting-gms per culture 1st	2nd	3rd	4th	Total
No	9.76	13.00	7.26	3.27	33.29
K	11.10	14.56	9.33	5.04	40.03
B	9.31	12.45	6.60	3.03	31.39
Mg	9.16	11.52	6.24	3.04	29.96
KB	10.57	13.83	9.57	4.82	39.79
KMg	10.11	13.83	9.46	4.94	38.34
BMg	8.54	10.83	8.29	3.87	31.53
KBMg	9.06	14.39	9.72	5.34	38.51
Significance of treatment affect	*	*	N.S.	*	**

Table 34. Analysis of variance for red clover yield data, Soil VI, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	12.6020	
Between replications	1	.0010	.0010
Between treatments	7	10.1927	1.4561*
K	1	4.14*	
B	1	1.75	
KB	1	.06	
Mg	1	3.77*(decrease)	
KMg	1	.32	
BMg	1	.12	
KBMg	1	.03	
Error	7	2.4143	.3449

Table 35. Analysis of variance for red clover yield data, Soil VI, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	32.3065	
Between replications	1	.7267	.7267
Between treatments	7	25.8628	3.6947*
K	1	19.30**	
B	1	.49	
KB	1	.28	
Mg	1	2.78	
KMg	1	2.16	
BMg	1	.34	
KBMg	1	.51	
Error	7	5.7170	.8167

Table 36. Analysis of variance for red clover yield data, Soil VI, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	45.1791	
Between replications	1	.5550	.5550
Between treatments	7	28.5122	4.0732
Error	7	16.1119	2.3017

Table 37. Analysis of variance for red clover yield data, Soil VI, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	15	16.5678	
Between replications	1	.0144	.0144
Between treatments	7	13.2252	1.8893*
K	1	12.01**	
B	1	.15	
KB	1	.04	
Mg	1	.25	
KMg	1	.01	
BMg	1	.71	
KBMg	1	.05	
Error	7	3.3282	.4755

Table 38. Analysis of variance for combined data, Soil VI.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	63	756.1604	
Between replications	4	1.2971	.3243
Between treatments	7	58.0818	8.2974**
K	1	54.38**	
B	1	.12	
KB	1	.03	
Mg	1	1.69	
KMg	1	.09	
BMg	1	1.50	
KBMg	1	.27	
Between cuttings	3	649.3988	216.4663**
Treatments x cuttings	21	19.7115	.9386
Error	28	27.6712	.9811

Table 39. Effect of chemical treatment on mean yield of red clover, by cuttings, all soils combined.

Treatment	Yield by cutting-gms per culture			
	1st	2nd	3rd	4th
No	8.25	10.47	6.09	2.90
K	9.43	13.29	9.12	4.40
B	8.08	10.60	6.14	3.17
Mg	7.92	10.43	6.46	3.49
KB	9.89	13.98	9.38	5.00
KMg	8.67	12.92	8.77	4.68
BMg	7.96	9.96	6.69	3.32
KBMg	8.81	14.04	10.02	5.25

Table 40. Analysis of variance for red clover yield data, first cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	95	498.3677	
Between replications	6	6.6195	1.1032
Between treatments	7	43.7690	6.25**
K	1	31.39**	
B	1	.33	
KB	1	.81	
Mg	1	7.88**(decrease)	
KMg	1	2.92	
BMg	1	.01	
KBMg	1	.42	
Between soils	5	351.6190	70.32**
Soil x treatments	35	50.7968	1.45
Error	42	45.5634	1.08

Table 41. Analysis of variance for red clover yield data, second cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	95	572.0404	
Between replications	6	37.0546	6.1758
Between treatments	7	258.0023	36.7575**
K	1	244.86**	
B	1	3.28	
KB	1	6.61*	
Mg	1	1.48	
KMg	1	.19	
BMg	1	.05	
KBMg	1	1.53	
Between soils	5	51.1782	10.2356**
Soils x treatments	35	157.7699	4.5077
Error	42	68.0354	1.6199

Table 42. Analysis of variance for red clover yield data, third cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	95	437.9480	
Between replications	6	1.9196	.3199
Between treatments	7	225.1427	32.1632**
K	1	212.21**	
B	1	4.81	
KB	1	2.24	
Mg	1	2.27	
KMg	1	.59	
BMg	1	2.05	
KBMg	1	.97	
Between soils	5	69.0657	13.8131**
Soils x treatments	35	89.6779	2.5622**
Error	42	52.1421	1.2415

Table 43. Analysis of variance for red clover yield data, fourth cutting.

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	95	124.5174	
Between replications	6	5.8791	.9799*
Between treatments	7	69.5442	9.9349**
K	1	62.33**	
B	1	2.42*	
KB	1	1.69*	
Mg	1	2.43*	
KMg	1	.07	
BMg	1	.35	
KBMg	1	.25	
Between soils	5	16.3163	3.2633**
Soils x treatments	35	17.5390	.5011
Error	42	15.2388	.3628

portant to note the highly significant variation among soils in Table 41.

Third Cutting. A study of the yield data showed considerable variation among treatments. By making a study of the analysis of variance table for the third cutting, it may be learned that the influence of treatments was highly significant. The analysis of variance indicated a highly significant effect of potassium.

A highly significant difference was indicated among the soils. This is especially important since it shows that all the soils studied did not react in the same ways. The highly significant interaction between soils and treatments was indicated by the data, also. This indicates that the various treatments reacted in different ways in the various soils.

Fourth Cutting. The small yields that were obtained at the time of the fourth cutting are shown again when the mean yields from all soils are studied. A highly significant influence of treatments was again indicated by the analysis of variance data. This influence was manifested in increased yields as a result of adding several elements. The effect of potassium was highly significant. The data also indicated a significant effect resulting each from boron, magnesium, and the interaction of potassium and boron. The greater response at the fourth cutting may have been some indication of nutrient deficiences which had developed on these soils. The variation among soils was shown in the data again at the time of the fourth harvest. This effect was highly significant. The variation between replications was significant, also.

Chemical Analyses of Plant Material

A consideration will first be given to the chemical composition of each soil and to each cutting of clover taken from each soil with respect to the treatment. All values are means of duplicate samples.

Since phosphorus was applied to all jars in the same amount, any variation in the phosphorus content of the plant material might be expected to be due to the influence of other elements upon the uptake of phosphorus by the plant or differences due to the amount of clover produced.

Any differences in the phosphorus content of the plant might be considered a result of the influences of other elements since there were no significant differences between yields of clover on the various cultures of Soil I at the time of the first cutting. The plants produced in cultures receiving no treatment, potassium, potassium boron, and potassium magnesium contained less phosphorus than those grown in the other four cultures. It was noted that with the exception of the potassium boron magnesium treatment the plants that were higher in magnesium were also higher in phosphorus. In the case of treatments potassium, boron, magnesium, potassium boron, and potassium boron magnesium the phosphorus content of the plant decreased with each successive cutting. The phosphorus content of the plant material from the other treatments showed a sharp decrease and then an increase in phosphorus content with cutting. In no case did the phosphorus content of the later cuttings exceed that of the first cutting.

Table 44. Chemical composition of red clover grown on the Cherokee subsoil (Soil I).

Treat-ment	Elements and cuttings														
	Percent												ppm		
	Phosphorus				Potassium				Magnesium				Boron		
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd
No	.230	.182	.204	.218	1.210	1.034	1.038	.763	.618	.588	.694	1.125	7.5	8.3	7.3
K	.229	.213	.189	.185	2.723	2.669	2.099	1.584	.557	.420	.498	.930	3.1	7.4	8.0
B	.263	.196	.194	.188	1.396	.981	1.007	.719	.832	.605	.770	1.070	43.0	68.0	58.0
Mg	.258	.201	.193	.180	1.408	1.082	.919	.682	.824	.671	.664	.969	12.7	8.5	8.2
KB	.231	.190	.192	.163	2.207	2.446	1.676	1.410	.684	.465	.572	.711	42.0	57.3	60.2
KMg	.224	.157	.189	.203	2.280	1.872	2.497	2.172	.544	.454	.582	..977	10.7	11.1	9.0
BMg	.249	.216	.178	.210	1.268	1.005	.900	.774	.859	.837	.630	1.2373	38.7	62.5	65.7
KBMg	.250	.182	.170	.157	2.544	2.209	1.753	1.263	.562	.497	.583	.828	33.5	46.7	55.5

The potassium content of the plant material decreased with each cutting for all treatments except potassium boron and potassium magnesium. In all cases where potassium was applied to the soil the potassium content of the plant material was greater than where potassium had not been applied to the soil. If the critical limits for potassium in the plant found by Hunter, Toth, and Bear should apply to this experiment no response to applied potassium would have been expected at the time of the first cutting because the potassium content of the plant exceeded 1 per cent (10). As previously mentioned in the discussion of yields potassium did not significantly increase the yields of the first cutting but did increase the yields of the last three cuttings. The critical limits of potassium in the plant material from this soil appears to be about 1.1 per cent since the potassium content of the clover at the time of the second cutting is just under this figure where no potassium had been added.

In general, the concentration of magnesium in the plant was greater where magnesium had been applied to the soil unless magnesium was applied in combination with potassium. The greater supply of potassium in the soil under such conditions apparently repressed the uptake of magnesium by the plant. The plants from the boron and no treatment cultures at the time of the third and fourth cutting contained more magnesium than did the plants grown on the magnesium culture. The soil was becoming potassium deficient at that time and since there was a good supply of soil magnesium the clover took up a greater proportion of magnesium. Less magnesium was contained in the plant in the second harvest than in the first. The magnesium content increased after the second cutting and was greatest in the fourth cutting. The yield of the fourth cutting was much lower.

A pronounced difference in boron content of the plant material was observed as a result of applications of boron. The amount of boron contained in the plants grown on the soil treated with borax increased with cutting with the exception of the third cutting. The low boron content of clover where boron was not applied might be considered indicative of a boron deficient soil.

More phosphorus was contained in the plant material from Soil II in all cuttings and for all treatments than was true for Soil I. The phosphorus content of the plant decreased with each cutting when an application of boron was made. An increase in phosphorus may be noted for each successive cutting from cultures receiving the potassium and potassium magnesium treatments. All the other treatments resulted in a decreased phosphorus content and then an increase with the third or fourth cutting.

A negative relationship seems to exist between the amount of potassium and magnesium absorbed by the plants. The effect of the potassium concentration in the soil on magnesium uptake by the plant is greater than the effect of magnesium on potassium uptake. This is indicated by the fact that less magnesium was taken by the plant when potassium was applied,

Table 45. Chemical composition of red clover grown on Soil II.

Treatment	Elements and cuttings														
	Percent												ppm		
	Phosphorus				Potassium				Magnesium				Boron		
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd
No	.280	.278	.250	.377	1.137	1.033	.981	.979	.489	.499	.447	.564	32.6	27.0	23.8
K	.254	.254	.281	.372	2.005	2.210	2.422	1.730	.335	.381	.435	.413	30.0	28.0	28.2
B	.258	.233	.249	.237	1.157	1.388	1.036	.790	.800	.431	.471	.851	47.2	66.0	70.1
Mg	.314	.266	.254	.438	1.280	.997	1.008	.739	.683	.529	.507	.849	34.2	30.5	31.5
KB	.282	.250	.296	.270	2.825	2.328	2.178	1.406	.416	.353	.445	.541	41.5	67.5	66.1
KMg	.254	.281	.282	.326	2.495	2.434	2.176	1.516	.505	.421	.475	1.056	30.5	27.9	27.5
BMg	.327	.288	.302	.423	1.250	1.129	1.124	.882	.570	.541	.458	.812	51.6	67.5	63.2
KBMg	.325	.245	.270	.294	2.464	2.046	1.753	1.049	.467	.448	.440	.701	46.8	57.1	58.8

and applied magnesium did not reduce the uptake of potassium. This is also indicated by the fact that more magnesium was contained in the plant when magnesium was applied to the soil unless magnesium was applied in combination with potassium. The potassium content of the plant was greater when potash had been applied to the soil. The potassium of the plants decreased with each cutting when potash was applied. The greatest amount of magnesium was contained by the plants at the time of the last cutting. Considering 1 per cent potassium in the plant as a critical low value, a yield response to potassium could be expected from this soil for the third and fourth cuttings. By refering to the statistical analysis of the yield data it may be noted that a highly significant response was obtained from both cuttings. A significant response was obtained from the application of magnesium for these cuttings.

The boron content of the red clover produced on Soil II was considerably greater than on Soil I. More boron was taken by the plant when boron was applied to the soil and the magnitude of this difference became greater with each succeeding cutting.

Soil III and Soil IV will be considered together and only differences will be pointed out on the individual soils.

A closer relationship between the uptake of phosphorus and magnesium by the plant was evident for these soils than was observed for Soil II. The first and last cuttings contained the most phosphorus with the fourth cutting taking slightly the most from the soil.

Table 46. Chemical composition of red clover grown on Soil III.

Treatment	Elements and cuttings: Percent: Phosphorus 1st	2nd	3rd	4th	Potassium 1st	2nd	3rd	4th	Magnesium 1st	2nd	3rd	4th	ppm Boron 1st	2nd	3rd
No	.333	.270	.294	.335	.873	.537	.800	.695	.561	.547	.537	.764	46.5	35.1	36.5
K	.300	.241	.246	.307	2.649	1.330	.955	.930	.370	.401	.303	.576	41.5	31.2	27.2
B	.295	.271	.335	.527	.653	.524	.652	.653	.602	.529	.598	.764	62.5	95.0	77.7
Mg	.378	.256	.285	.397	.893	.568	.776	.601	.696	.542	.573	.804	52.2	39.4	35.5
KB	.293	.251	.269	.360	2.715	1.360	1.263	.792	.300	.393	.429	.543	55.0	82.0	73.4
KMg	.343	.258	.264	.343	2.836	1.685	1.179	.876	.353	.432	.373	.570	46.5	34.2	29.0
BMg	.353	.278	.305	.408	.878	.536	.758	.667	.685	.553	.515	.772	56.7	94.0	84.0
KBMg	.298	.226	.254	.355	3.003	1.540	1.575	1.032	.399	.430	.399	.649	50.1	75.3	72.[illegible]

Table 47. Chemical composition of red clover grown on Soil IV.

Treatment	Elements and cuttings														
	Percent												ppm		
	Phosphorus				Potassium				Magnesium				Boron		
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd
No	.364	.322	.332	.392	.746	.532	.661	.618	.667	.657	.562	.748	52.5	37.8	29.5
K	.294	.270	.260	.404	2.473	1.322	1.021	.896	.377	.497	.411	.733	33.6	32.7	25.7
B	.300	.302	.332	.346	.680	.590	.727	.627	.717	.696	.526	.772	66.0	90.5	78.0
Mg	.380	.334	.377	.425	.708	.535	.673	.554	.831	.805	.607	.928	50.0	44.7	27.8
KB	.312	.240	.253	.308	2.554	1.126	1.107	.770	.593	.470	.448	.713	52.8	74.6	63.0
KMg	.310	.270	.273	.352	2.499	1.311	1.212	.774	.393	.480	.434	.756	29.1	29.2	26.4
BMg	.388	.327	.415	.415	.662	.607	.829	.601	.540	.771	.617	.976	69.2	96.0	94.0
KBMg	.300	.246	.306	.358	2.486	1.388	1.197	.781	.363	.471	.489	.836	46.7	73.3	69.0

The plants grown on Soil III contained slightly more potassium than those grown on Soil IV. The potassium content of the clover decreased sharply with each cutting. A rather close negative relationship existed between the uptake of potassium and magnesium. The amount of potassium and magnesium taken by the plant was closely related to the potassium concentration in the soil, with potassium repressing the uptake of magnesium. More magnesium was taken up by the plant when magnesium had been applied to the soil except when magnesium was applied in combination with potassium. The uptake of magnesium was greater when magnesium had been added to the soil either alone or in combination with boron.

Soils III and IV showed a greater uptake of boron than did Soils I and II. Again more boron was taken up when boron had been applied to the soil. Less difference may be observed between the amount of boron taken up where boron was applied and where it was not applied to the soil.

Soils V and VI belong to the soil type Cherokee silt loam and are discussed together. The composition of the red clover removed from these soils is given in Tables 48 and 49.

The phosphorus content of the clover grown on these soils does not vary to any extent in the case of the first three cuttings as a result of treatments. In the fourth cutting the phosphorus content was highest when magnesium had been applied to the soil alone or in combination with boron. This suggests a relationship between the uptake of these two elements. More magnesium was contained in the plant material of the fourth cutting. The uptake of magnesium was greater when magnesium had been added to the soil either alone or in combination with boron.

The same negative relationship was apparent between potassium and magnesium in the plant as was observed in the other soils. The added potash increased the potassium content of the plant over the no potash treatment in all cuttings. The added boron increased the boron content of the plant material as was true for the other soils.

Table 48. Chemical composition of red clover grown on Soil V.

Treat- ment	Elements and cuttings														
	Percent												ppm		
	Phosphorus				Potassium				Magnesium				Boron		
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd
No	.322	.260	.292	.472	.869	.783	1.082	.629	.588	.557	.405	.764	36.0	34.5	30.3
K	.304	.237	.286	.396	2.521	1.800	1.652	.882	.439	.420	.387	.644	24.4	30.9	26.4
B	.352	.256	.286	.381	.950	.770	.944	.719	.601	.517	.375	.632	71.6	113.0	79.5
Mg	.302	.238	.306	.445	.948	.759	1.008	.796	.800	.517	.422	.874	36.0	29.8	24.4
KB	.312	.224	.286	.320	2.724	1.859	1.703	1.158	.439	.361	.422	.617	48.1	89.5	79.2
KMg	.272	.233	.266	.321	2.523	1.932	1.657	1.195	.412	.407	.407	.572	20.0	27.4	24.3
BMg	.312	.235	.291	.469	.922	.783	1.005	.940	.722	.515	.447	.741	60.2	96.4	73.0
KBMg	.236	.252	.296	.340	2.746	2.011	1.901	1.263	.410	.416	.418	.541	49.0	97.0	79.0

Table 49. Chemical composition of redclover grown on Soil VI.

Treat-	Elements and cuttings														
	Percent												ppm		
	Phosphorus				Potassium				Magnesium				Boron		
ment	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd
No	.266	.242	.278	.450	.988	.770	.935	.801	.678	.491	.442	.926	40.0	29.1	25.9
K	.266	.244	.290	.371	2.616	1.712	1.575	1.054	.399	.416	.391	.863	30.6	30.4	22.8
B	.346	.250	.263	.385	1.122	.859	.858	.766	.597	.517	.505	.951	82.0	100.0	64.6
Mg	.346	.296	.284	.428	1.078	.855	.859	.854	.770	.624	.646	1.002	43.5	33.4	22.0
KB	.257	.220	.278	.329	2.306	1.769	1.624	1.138	.283	.398	.367	.814	53.0	77.0	79.2
KMg	.308	.238	.280	.394	2.660	1.899	1.597	1.126	.459	.383	.355	.833	36.3	23.0	25.7
BMg	.301	.276	.306	.392	1.073	.943	.950	.907	.537	.545	.502	1.013	63.1	93.5	85.0
KBMg	.261	.232	.286	.333	2.488	1.910	1.767	1.142	.403	.379	.395	.865	53.0	87.0	67.0

In order to consider the overall effect of growing four crops of red clover on the soil as the chemical composition of the plants may reflect, Tables 50 to 55, inclusive have been assembled showing the mean chemical content of the plant material from each soil.

From a study of Table 50 it may be noted that the potassium content of the plant was greater when potash had been applied to the soil. The uptake of potassium was less when potassium was applied to the soil in combination with boron. Possibly the increased concentration of sodium in the soil, a result of sodium added in the boron compound, depressed the uptake of potassium by the plant.

Table 50. Mean chemical composition of four cuttings of red clover, Soil I.

Treatment	Percent			ppm
	Phosphorus	Potassium	Magnesium	Boron
No	.209	1.011	.756	7.7
K	.204	2.268	.601	6.2
B	.211	1.026	.819	56.3
Mg	.208	1.023	.782	9.8
KB	.194	1.935	.608	53.2
KMg	.193	2.205	.639	10.3
BMg	.213	.987	.891	55.6
KBMg	.190	1.942	.618	45.2

For all treatments the addition of boron to the soil resulted in a tremendous increase in the boron content of the plant. The low values where boron was not added is indicative of a boron deficient soil.

The addition of magnesium alone or in combination with boron increased the magnesium content of the plant. Magnesium applied in combination with potassium did not increase the content of magnesium in the plant since the potassium prevented the uptake of magnesium. More magnesium was taken by the plant when no potassium or magnesium was applied than when potassium or any combination of potassium and magnesium was used. This is a result of a greater portion of the cations uptake being magnesium since the potassium supply was deficient in the soil.

Some associations between the quantity of phosphorus, magnesium, and potassium removed by the plant may be observed. With one exception, an increase in the magnesium uptake of the plant was always accompanied by an increase in the phosphorus uptake. This exception was observed with the potassium treatment. The magnesium content apparently did not increase because of the high concentration of potassium. As the potassium content of the plant increased the magnesium and phosphorus content decreased.

A rather high degree of association may be observed between the potassium content of the plant and yield response. When the potassium content fell below 1.026 per cent a highly significant yield response was obtained. On this soil a critical low value for potassium in the red clover was about 1-1.1 per cent and when this low was reached the soil was deficient in potassium.

By making a study of Table 51, it may be noted that any potassium treatment increased the potassium content of the red clover on Soil II. This increase was not as great for the

KBMg treatment. The effect of sodium or magnesium or a combination of factors may have affected the availability of potassium.

Table 51. Mean chemical composition of four cuttings of red clover, Soil II.

Treatment	Percent			ppm
	Phosphorus	Potassium	Magnesium	Boron
No	.296	1.033	.499	27.8
K	.290	2.092	.391	28.7
B	.244	1.093	.638	61.1
Mg	.318	1.006	.642	32.1
KB	.275	2.184	.439	58.4
KMg	.286	2.155	.614	28.6
BMg	.335	1.096	.595	60.8
KBMg	.283	1.828	.514	54.2

The addition of boron materially increased the boron taken by the plant. The uptake of boron was much greater in Soil II than Soil I when boron was not added to the soil. A response to boron would not be expected as readily on this soil as on Soil I; however, an overall highly significant response resulted. Studying the yield response by cutting only one response, for the third cutting, was noted.

The magnesium added served to increase the magnesium uptake when a comparison is made with the no treatment. The increase due to added magnesium was, however, no greater than that observed when boron was added. When potassium was applied without an application of magnesium, much less magnesium was taken by the plant. There are two possible explanations for this fact. High concentrations of potassium in the soil serve to decrease the uptake of magnesium and more plant material was removed from the soil when potassium was added. It would seem that the magnesium uptake resulting from the KMg and KBMg treatments would also be low. Some factor or combination of factors in this soil and different from Soil I must serve to decrease the activity of the potassium ions or increase the magnesium ion activity or both.

The relationship between the phosphorus and magnesium uptake is not apparent. The same general trend is followed but there are two exceptions. The B and KMg treatments resulted in a greater magnesium uptake by the plant. A negative relationship between uptake of magnesium and potassium was noted.

Yield response to potassium was obtained when the uptake of potassium dropped below 1 per cent. This low content of potassium in the plant served well to indicate potassium deficiency in the soil.

The uptake of nutrients by the red clover varied little between Soil III and Soil IV. The values are so near the same that the same trends may be observed. Because of this fact these soils will be discussed together. The effect of the previously added potassium in the field is shown by making a comparison of the per cent potassium contained in the plant.

As has been observed before, the addition of potassium increased the potassium uptake by the plant. The relatively large quantity of boron contained in the plant even when boron was not applied indicates that these soils were not boron deficient. The yield data substantuates this fact. It is interesting to note that when high yields were obtained, as was the case from the K and KMg treatments, there was a lesser concentration of boron in the plant.

Table 52. Mean chemical composition of four cuttings of red clover, Soil III.

Treatment	Percent Phosphorus	Percent Potassium	Percent Magnesium	ppm Boron
No	.309	.739	.602	39.4
K	.273	1.466	.412	33.3
B	.357	.629	.622	78.4
Mg	.329	.709	.654	42.4
KB	.293	1.532	.416	70.1
KMg	.302	1.644	.433	36.6
BMg	.337	.710	.631	78.2
KBMg	.283	1.802	.467	66.2

Table 53. Mean chemical composition of four cuttings of red clover, Soil IV.

Treatment	Percent Phosphorus	Percent Potassium	Percent Magnesium	ppm Boron
No	.352	.639	.658	39.9
K	.307	1.428	.504	30.7
B	.319	.656	.678	78.2
Mg	.379	.617	.792	40.8
KB	.278	1.389	.556	63.5
KMg	.301	1.449	.516	28.2
BMg	.386	.675	.726	86.4
KBMg	.303	1.463	.539	63.0

The Mg and BMg treatments resulted in a higher concentration of magnesium in the red clover. No more magnesium was taken by the plant when magnesium was included with potassium than when potassium was added alone. It seems that a certain amount of potassium and magnesium was taken regardless of the concentration of magnesium in these soils.

An association much closer than observed before is evident between the amounts of phosphorus and magnesium taken by the red clover. When the uptake of phosphorus and magnesium was increased the uptake of potassium was decreased.

The critical low for the amount of potassium in the plant when the soil became potassium deficient would certainly be no less than 1 per cent. These soils from near Thayer were the most potassium deficient soils studied.

There was little if any overall effect of the previously applied potassium in the field on Soil VI on the uptake of potassium by the red clover grown on this soil. The data for the two soils, V and VI, are so near the same that these soils may be considered together.

Table 54. Mean chemical composition of four cuttings of red clover, Soil V.

Treatment	Percent			ppm
	Phosphorus	Potassium	Magnesium	Boron
No	.337	.841	.578	33.6
K	.306	1.714	.472	27.0
B	.319	.846	.531	88.0
Mg	.323	.878	.653	30.1
KB	.286	1.861	.460	72.3
KMg	.273	1.827	.449	23.9
BMg	.327	.913	.606	76.5
KBMg	.281	1.980	.446	75.0

Table 55. Mean chemical composition of four cuttings of red clover, Soil VI.

Treatment	Percent Phosphorus	Percent Potassium	Percent Magnesium	ppm Boron
No	.309	.873	.634	31.7
K	.293	1.739	.517	27.9
B	.311	.901	.643	82.2
Mg	.338	.911	.760	33.0
KB	.271	1.709	.466	71.4
KMg	.305	1.820	.507	30.0
BMg	.319	.968	.649	80.5
KBMg	.278	1.826	.510	69.0

The same effect of applied potassium on the potassium uptake by the red clover that has been observed is in evidence here.

With regard to the effect of applied boron the same trend that has carried through may also be observed from these data. A study of these data will show that the boron concentration of the plant was lower and the yields were highest when no boron was applied.

The Mg and BMg treatments increased the magnesium uptake considerably. As much or more magnesium was taken by the plant when potassium was applied without magnesium as when magnesium was added together with potassium.

The association between the uptake of phosphorus and magnesium seemed closer in the case of Soil VI than Soil V. The phosphorus content of the plant material increased with each increase in magnesium. The same negative relationship noted before was present between the uptake of potassium and magnesium.

With reference to the discussion of the yield data, the overall significant response to added potassium may be associated with the per cent potassium uptake by the red clover. By refering to and studying Table 38 and associating these data with the data on yield response a critical low for potassium uptake by plants of about 1 per cent would seem in order for these soils. A slightly lower value might be more suitable for Soil V.

A consideration has been given to the nutrient uptake by red clover for each cutting by soil and for all cuttings for each soil. The overall influence of the treatments employed on all soils for all cuttings is summarized in Table 56.

Table 56. Mean chemical composition of plant material from all soils for all cuttings.

Treatment	Percent			ppm
	Phosphorus	Potassium	Magnesium	Boron
No	.302	.856	.623	30.0
K	.279	1.773	.504	25.7
B	.294	.870	.655	74.0
Mg	.316	.857	.714	31.3
KB	.266	1.727	.491	64.8
KMg	.277	1.850	.527	52.5
BMg	.319	.875	.686	73.0
KBMg	.270	1.809	.516	62.1

The effect of potassium added to all soils was one of increasing the potassium uptake of the plant. If the uptake of potassium were below a certain critical low this increase in potassium content was accompanied by an increase in yield.

Applications of boron increased the uptake of boron by the plant.

The overall influence of applied magnesium was of increasing the magnesium uptake when applied alone or in combination with boron. Applied potassium effected a decreased amount of magnesium uptake both when magnesium was applied with potassium or when potassium was applied alone. The fact that more magnesium was taken by the plant from the B and No treatment cutlures where potassium was low than from the potassium treated culture helps support the conclusion that potassium retards the uptake of magnesium.

The direct relationship existing between the phosphorus and magnesium uptake is apparent as is the inverse relationship existing between the potassium and magnesium uptake.

Phosphorus-Magnesium Relationships. After previously considering the apparent relationships existing between the uptake of phosphorus and magnesium by the red clover, it seemed desirable to determine the statistical significance of these observations. Whether or not the same positive correlation between phosphorus and magnesium that Troug et. al. (26) reported existing with peas applied to this experiment could be ascertained. The effective use of phosphate fertilizer may be somewhat dependent upon the magnesium supply of the soil if magnesium serves as a carrier of phosphorus. A knowledge of these phosphorus-magnesium relationships may be of practical value so far as these soils are concerned.

The relationship between phosphorus and magnesium uptake on Soil I for all harvests showed no significant correlation. A study of Fig. 1 indicated a lack of significant correlation.

This soil contained a rather high per cent of exchangeable magnesium both before and after growing the clover. This fact probably was responsible for the relatively large quantity of magnesium taken by the plant in relation to the uptake of phosphorus and the lack of correlation. The magnesium applied was not as effective in increasing the magnesium content of the clover grown on this soil as it was on the other soils studied.

By making a study of Fig. 2 the fact that there was a significant correlation between the uptake of phosphorus and magnesium was indicated for Soil II. The correlation coefficient closely approached that required for significance at the .01 level. This soil had less exchangeable magnesium than Soil I but considerably more than the other soils studied.

By referring to Figs. 3, 4, 5, and 6 which show the correlation coefficients for Soils III, IV, V, and VI, respectively, the significance may be noted. The correlation between the uptake of phosphorus and magnesium by the plants grown on each of these soils was significant at the .01 level of probability.

When the data for all soils were compiled and a correlation coefficient calculated it was shown that the degree of association between the uptake of phosphorus and magnesium was highly significant. Figure 7 shows this relationship.

When a study is made of the graphs where correlation was shown it may be noted that the correlation coefficients were positive and the regression line indicated a positive association. When the regression of phosphorus on magnesium was significant the role of magnesium in facilitating the uptake of phosphorus was indicated.

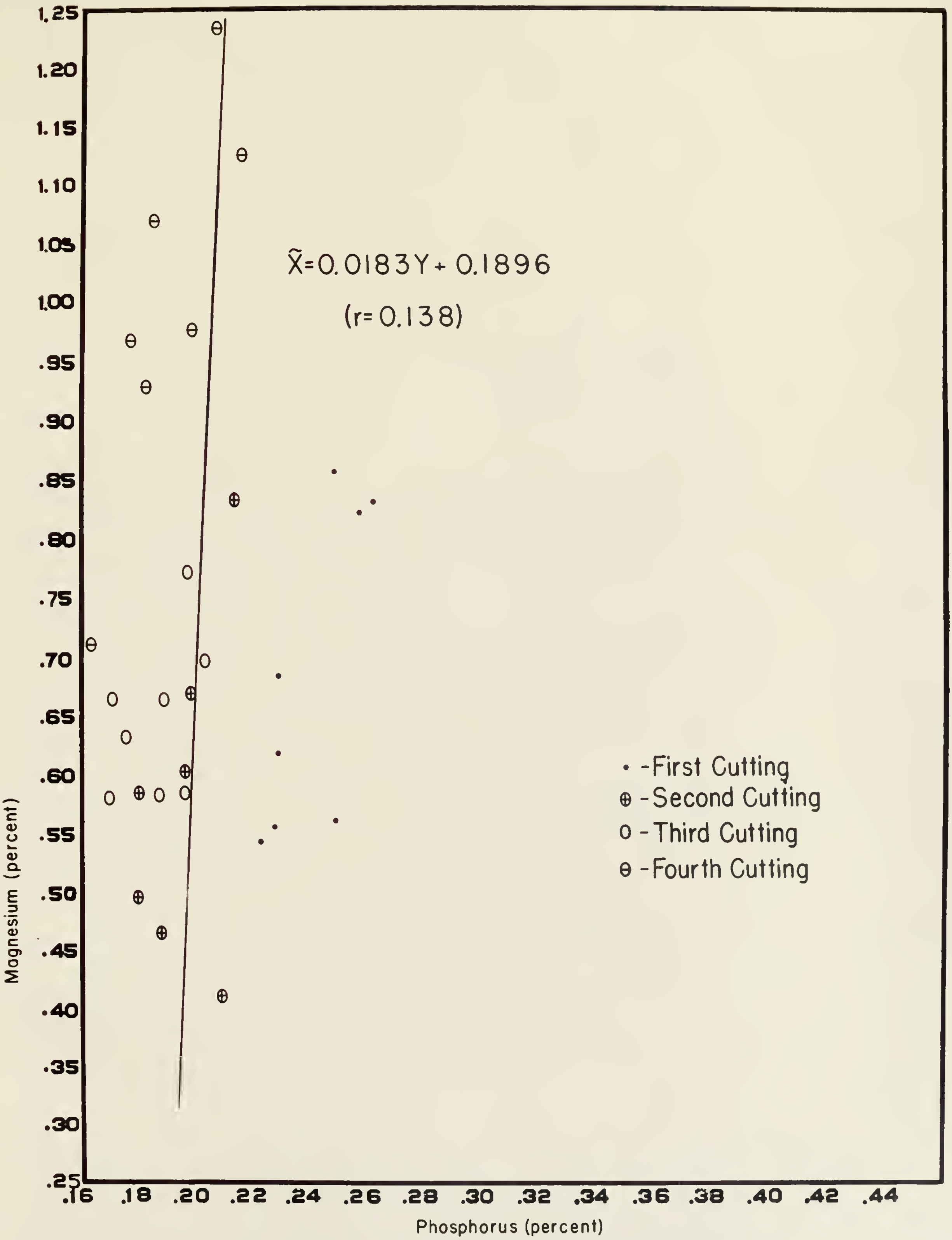

Fig. 1. Regression of phosphorus content (X) upon magnesium content (Y) for Soil I

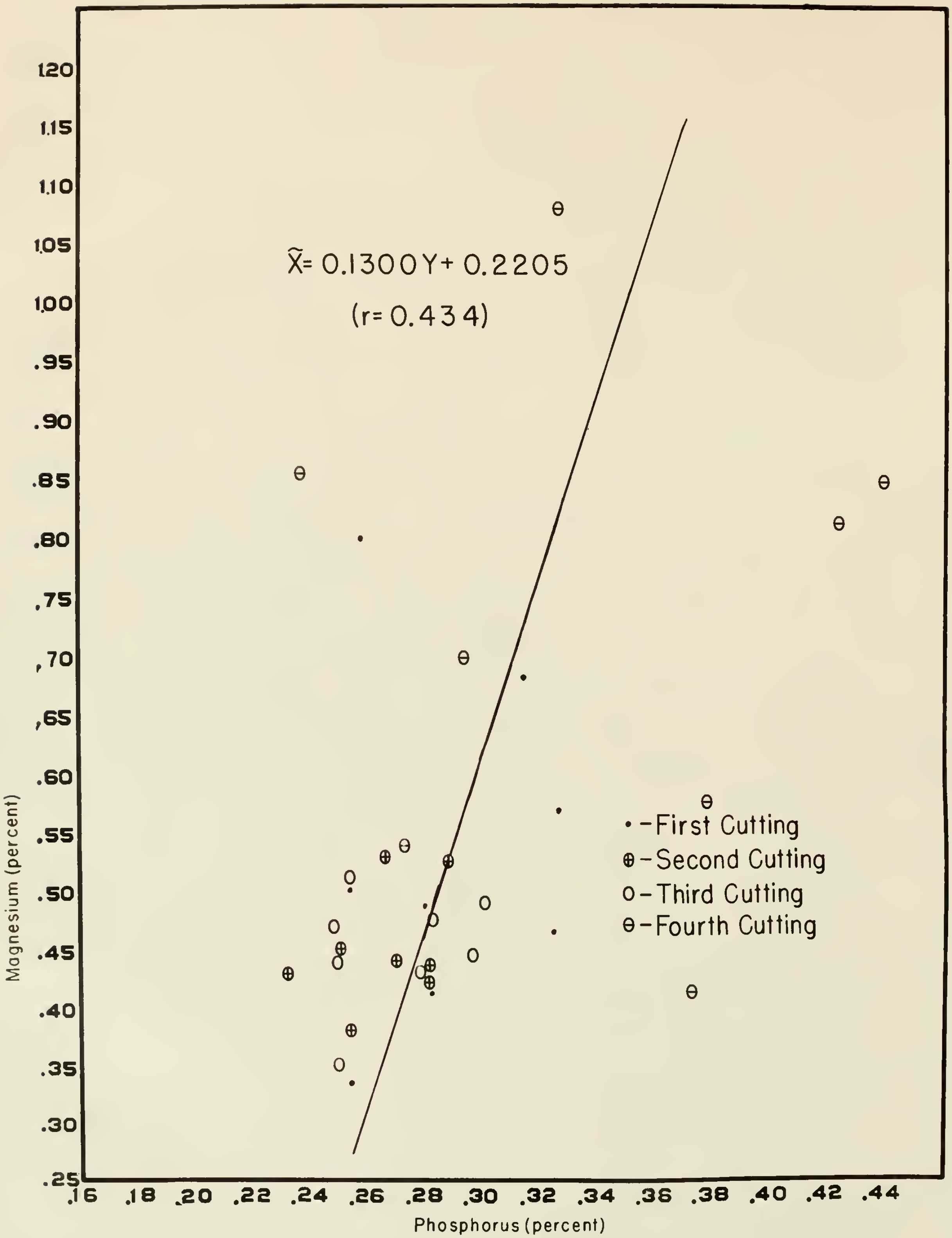

Fig. 2. Regression of phosphorus content (X) upon magnesium content (Y) for Soil II

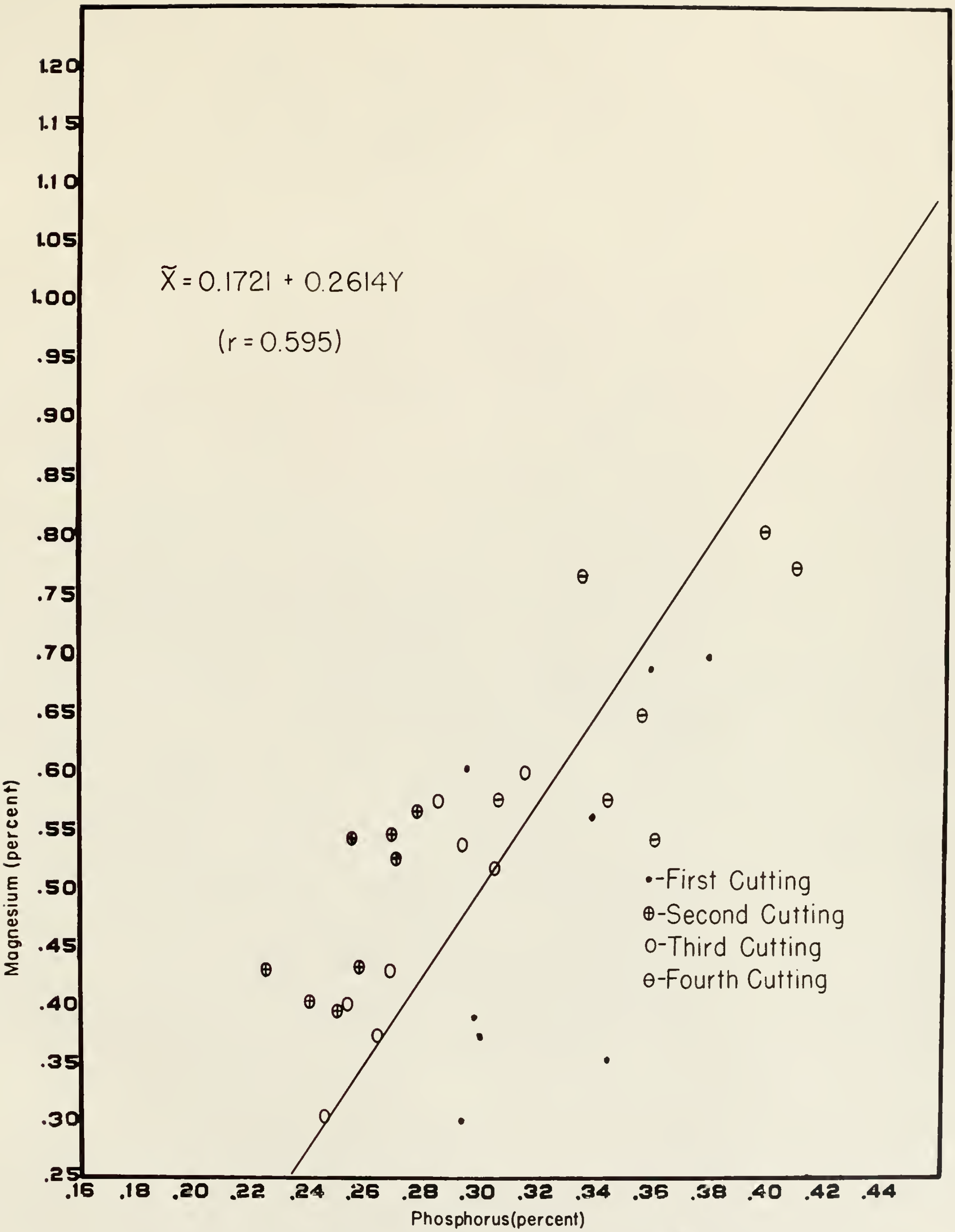

Fig.3. Regression of phosphorus content(X) upon magnesium content(Y) for Soil III

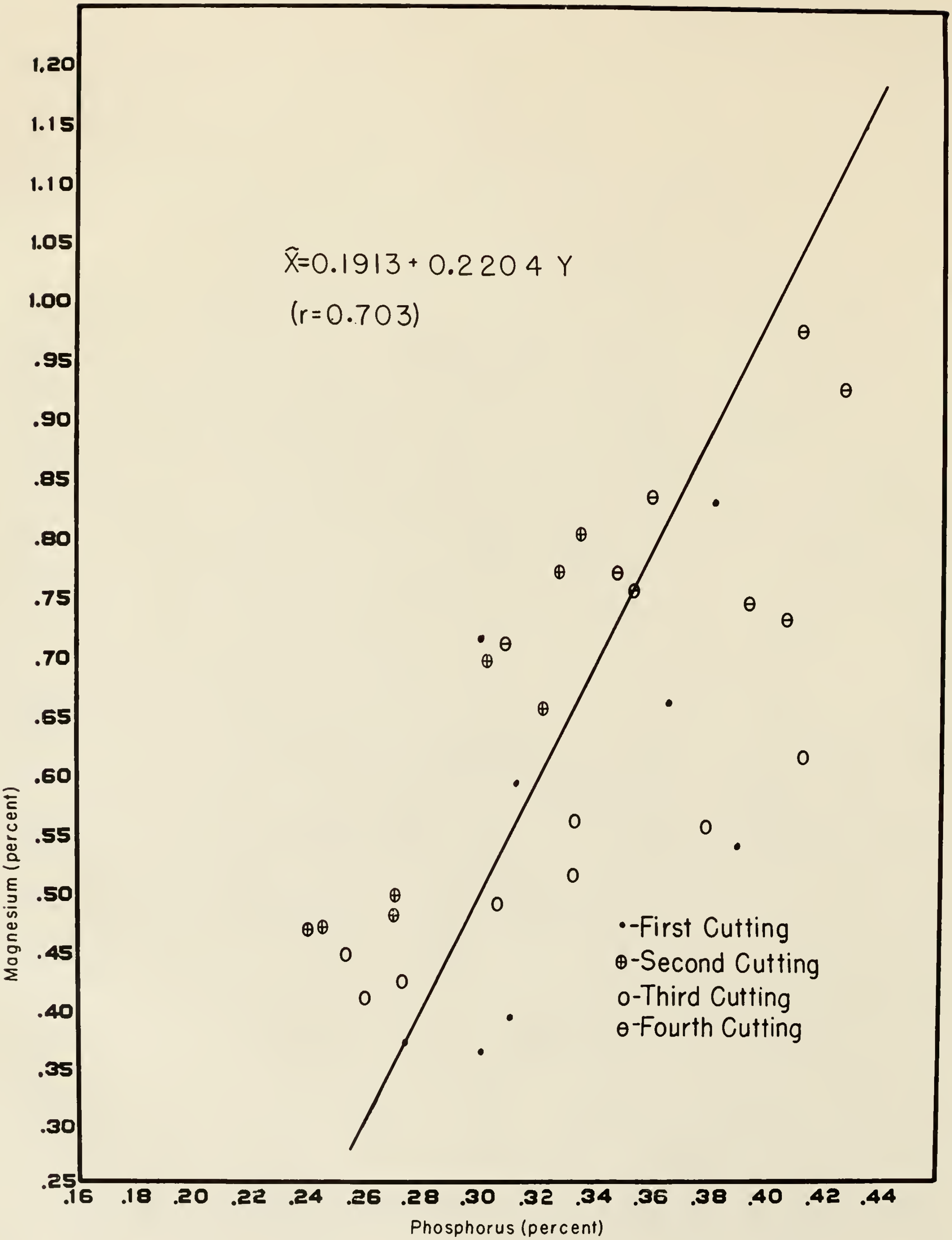

Fig. 4. Regression of phosphorus content (X) upon magnesium content (Y) for Soil IV

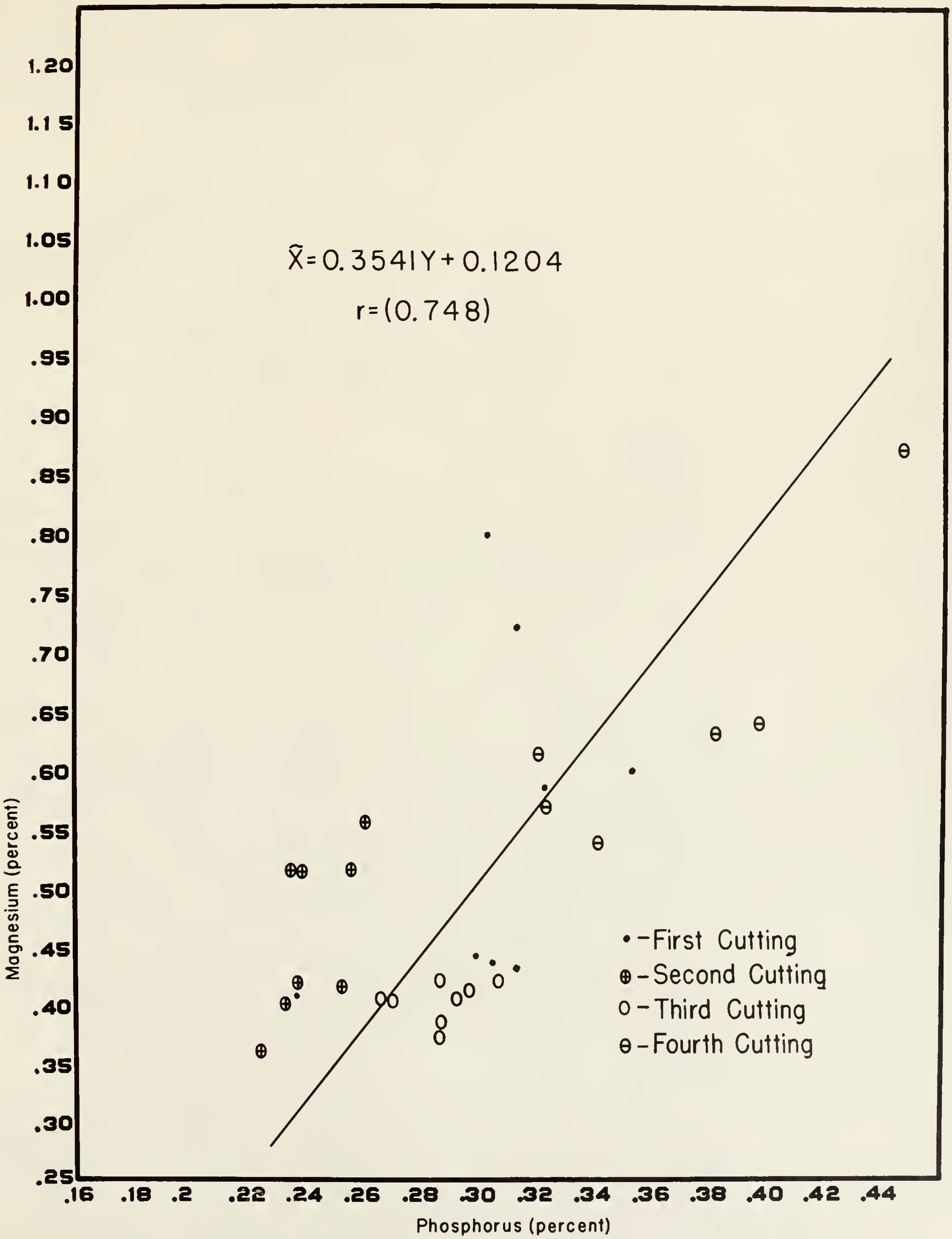

Fig. 5. Regression of phosphorus content (X) upon magnesium content (Y) for Soil V

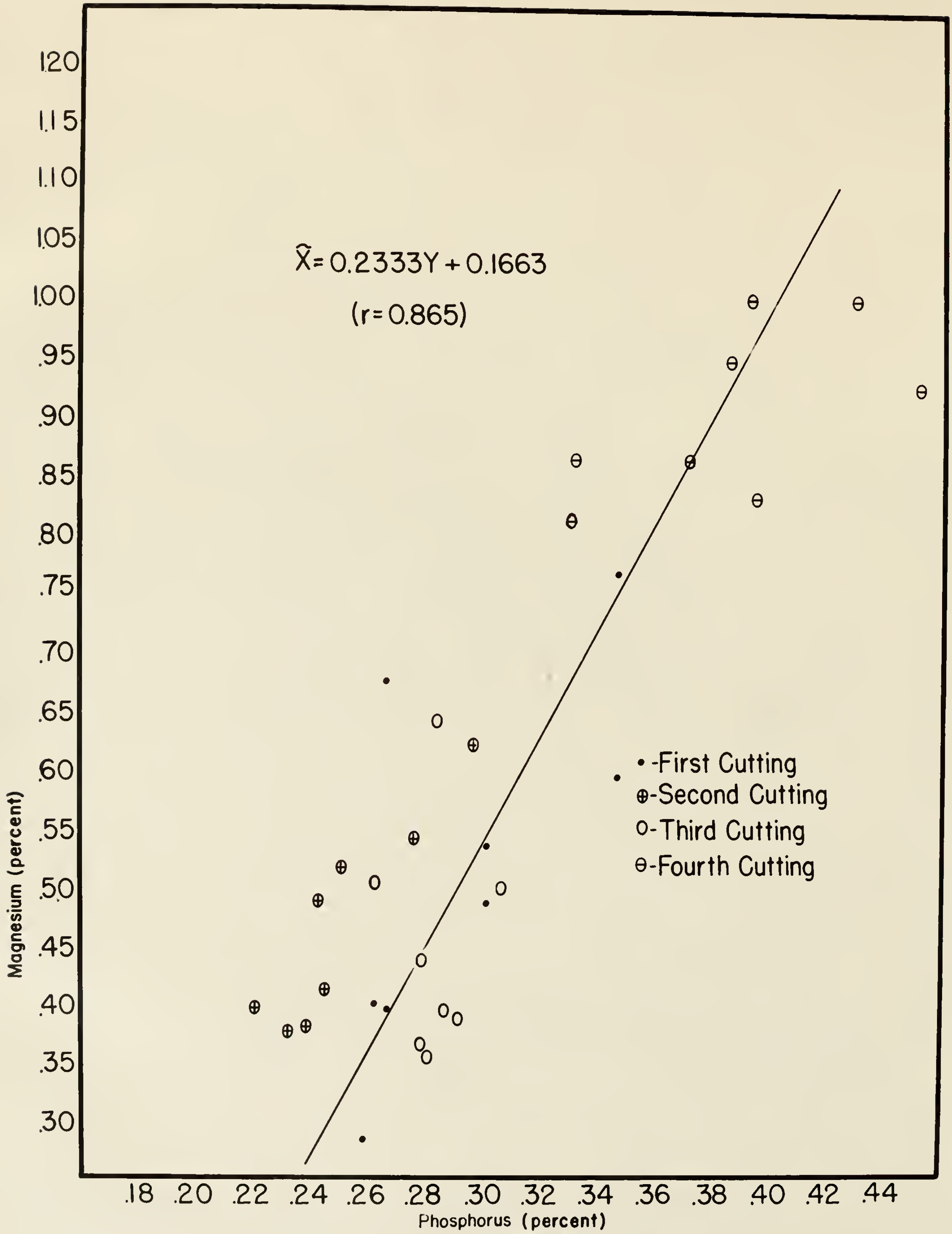

Fig. 6. Regression of phosphorus content (X) upon magnesium content (Y) for Soil VI

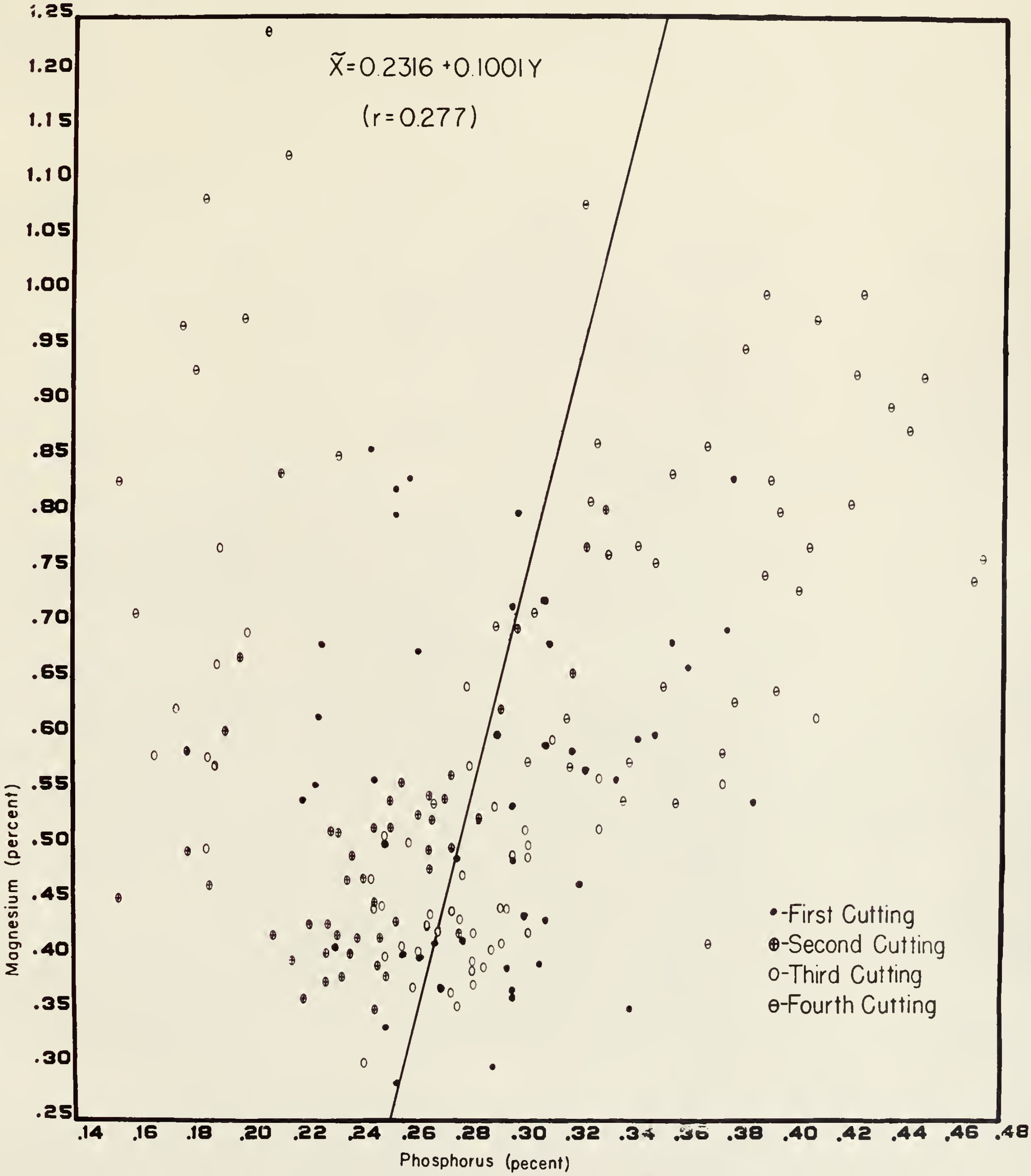

Fig 7 Regression of phosphorus content (X) upon magnesium content (Y) for all Soils

Potassium-Magnesium Relationships. Contentions have been made by some investigators (15, 17) that potassium supresses the uptake of magnesium and other cations by the plant. Since both potassium and magnesium were included as treatments in this experiment and these elements were determined in the plant material, an excellent opportunity was presented to study the relationship between the uptake of the elements. By observing the trends in the tables of the chemical data of the plant material a negative relationship was indicated.

Since the true value of this relationship could be ascertained only by a statistical treatment a correlation coefficient and regression line were computed for each soil. These data are illustrated in Figs. 8 to 14, inclusive. By making a study of all the graphs it may be concluded that all of the correlation values are highly significant. Another observation was that the value bears a negative sign and that the regression line was also negative.

An interpretation of these data leads to the conclusion that for each increase in potassium uptake by the plant there was a corresponding decrease in the uptake of magnesium. The findings of this investigation support the contentions of others that potassium suppresses the uptake of magnesium by the plant.

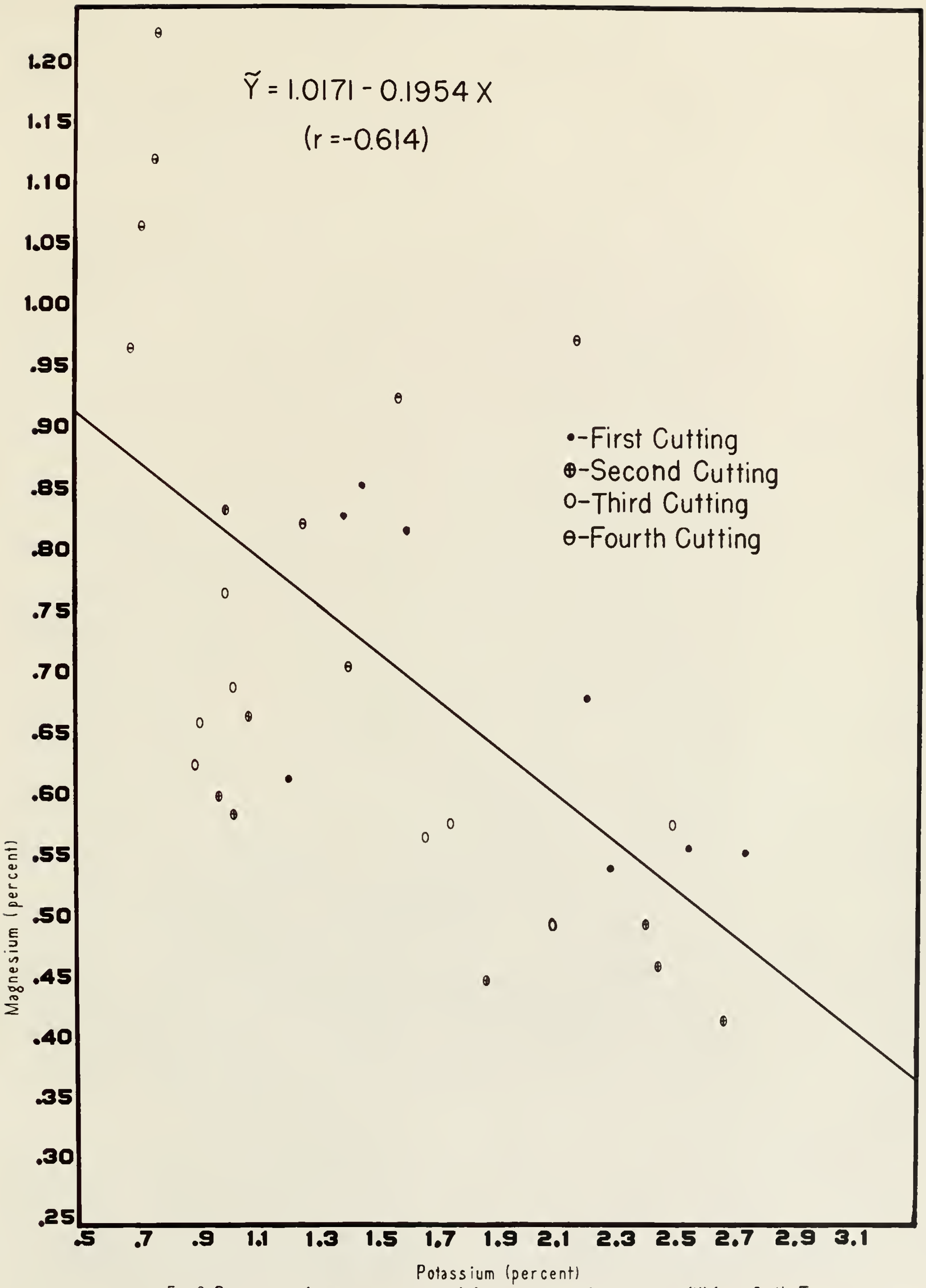

Fig.8. Regression of magnesium content (Y) upon potassium content (X) for Soil I

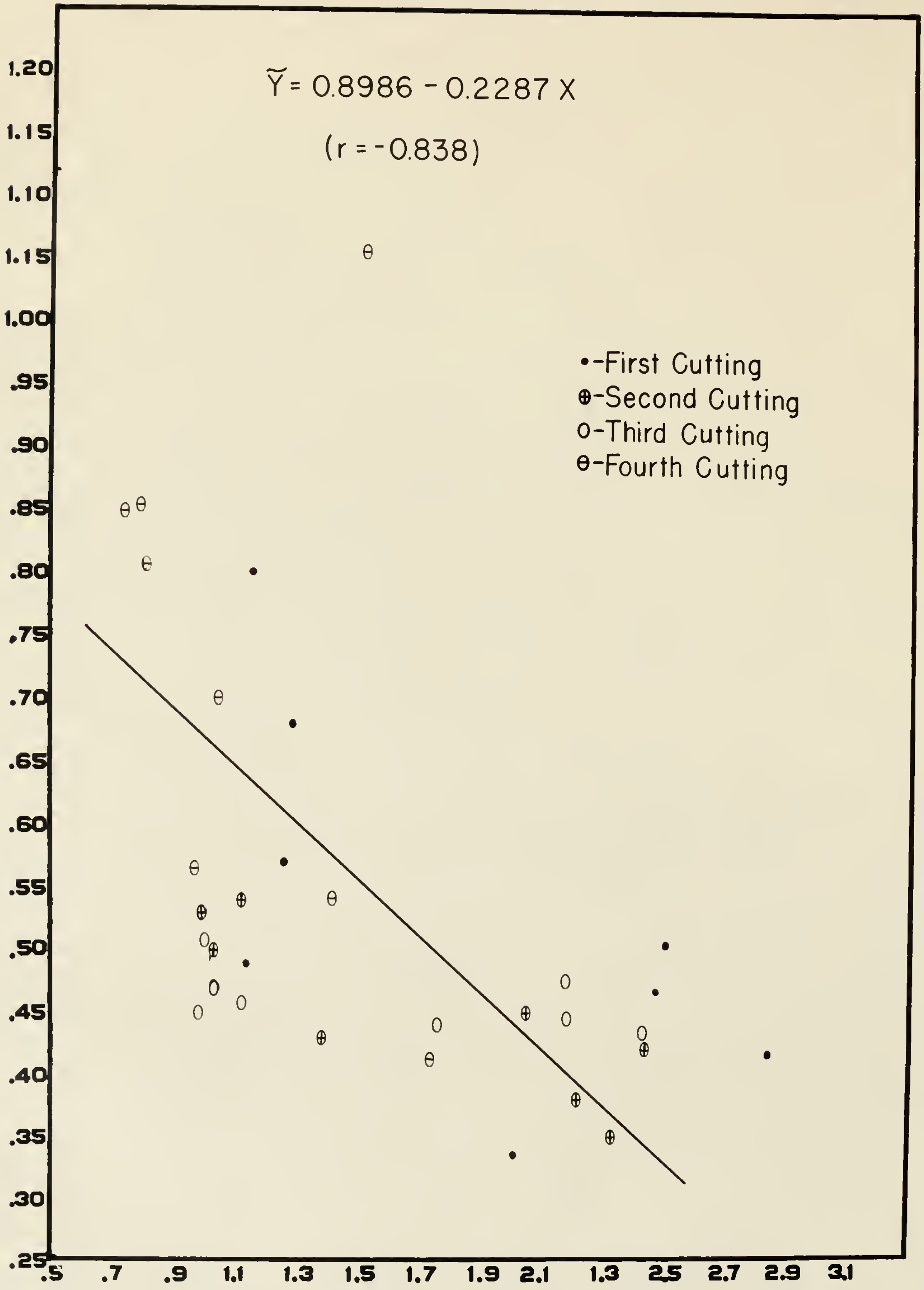

Fig. 9. Regression of magnesium content (Y) upon potassium content (X) for Soil II

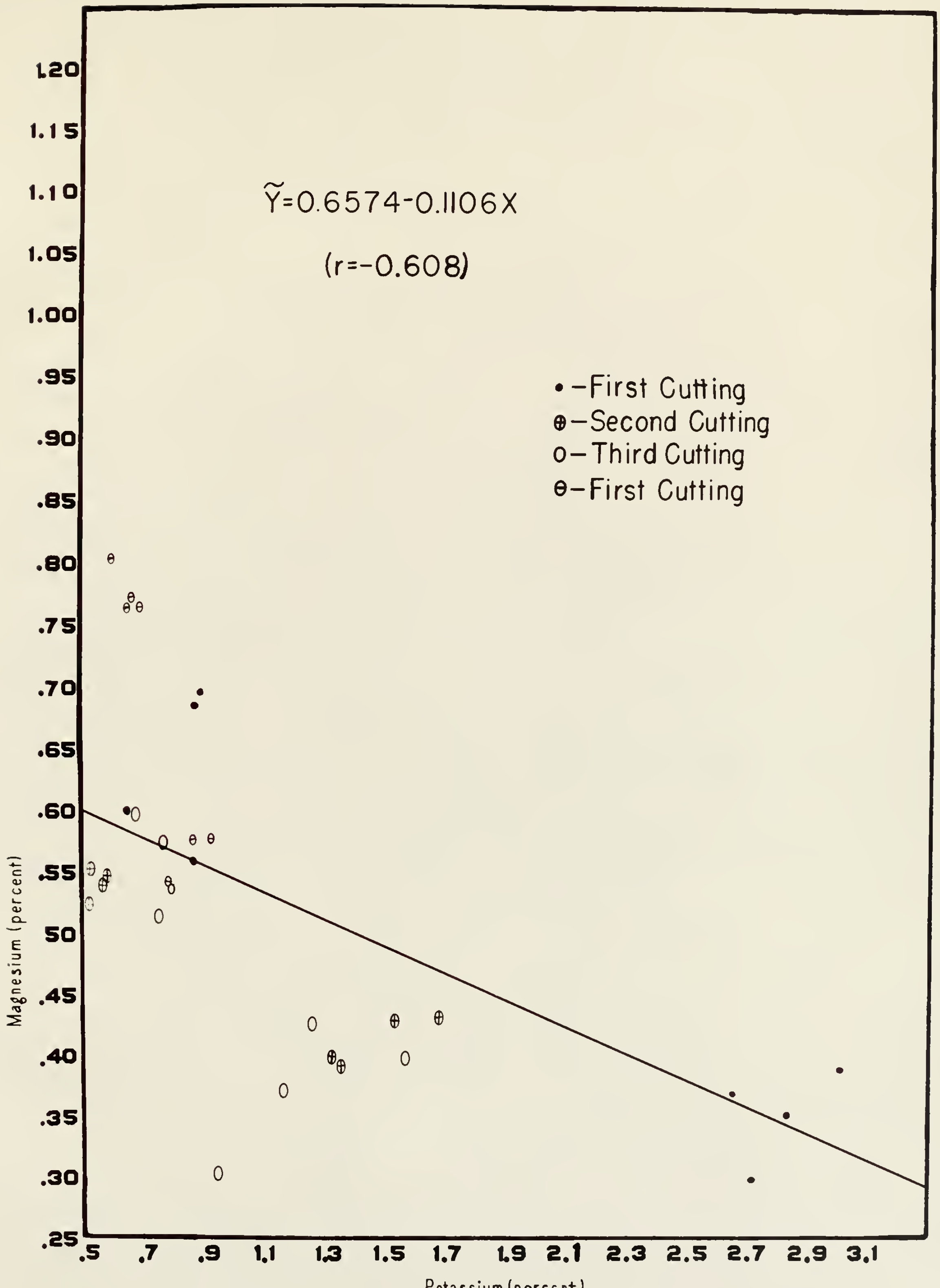

Fig. 10. Regression of magnesium content (Y) upon potassium centent (X) for Soil III

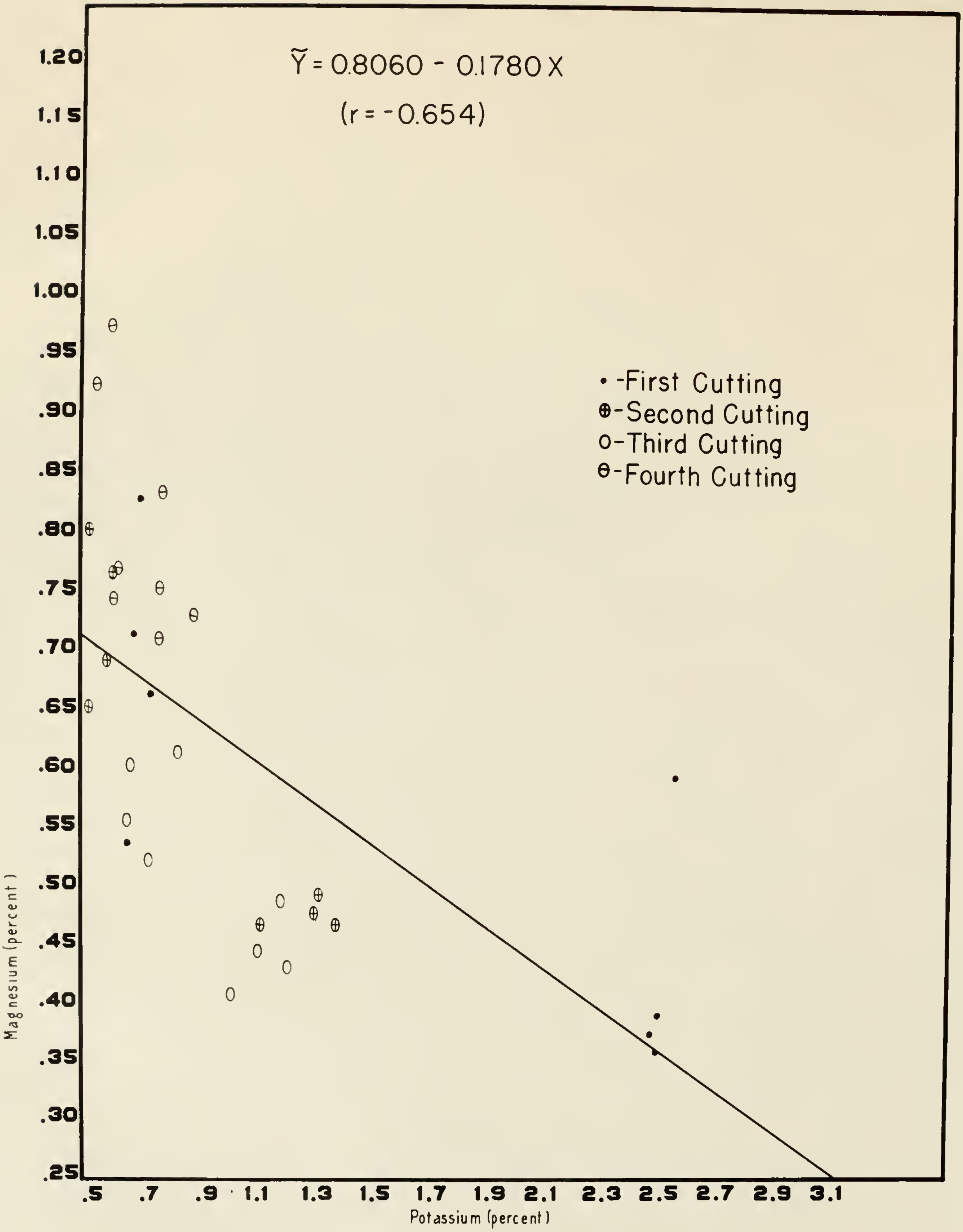

Fig.11. Regression of magnesium content (Y) upon potassium content (X) for Soil IV

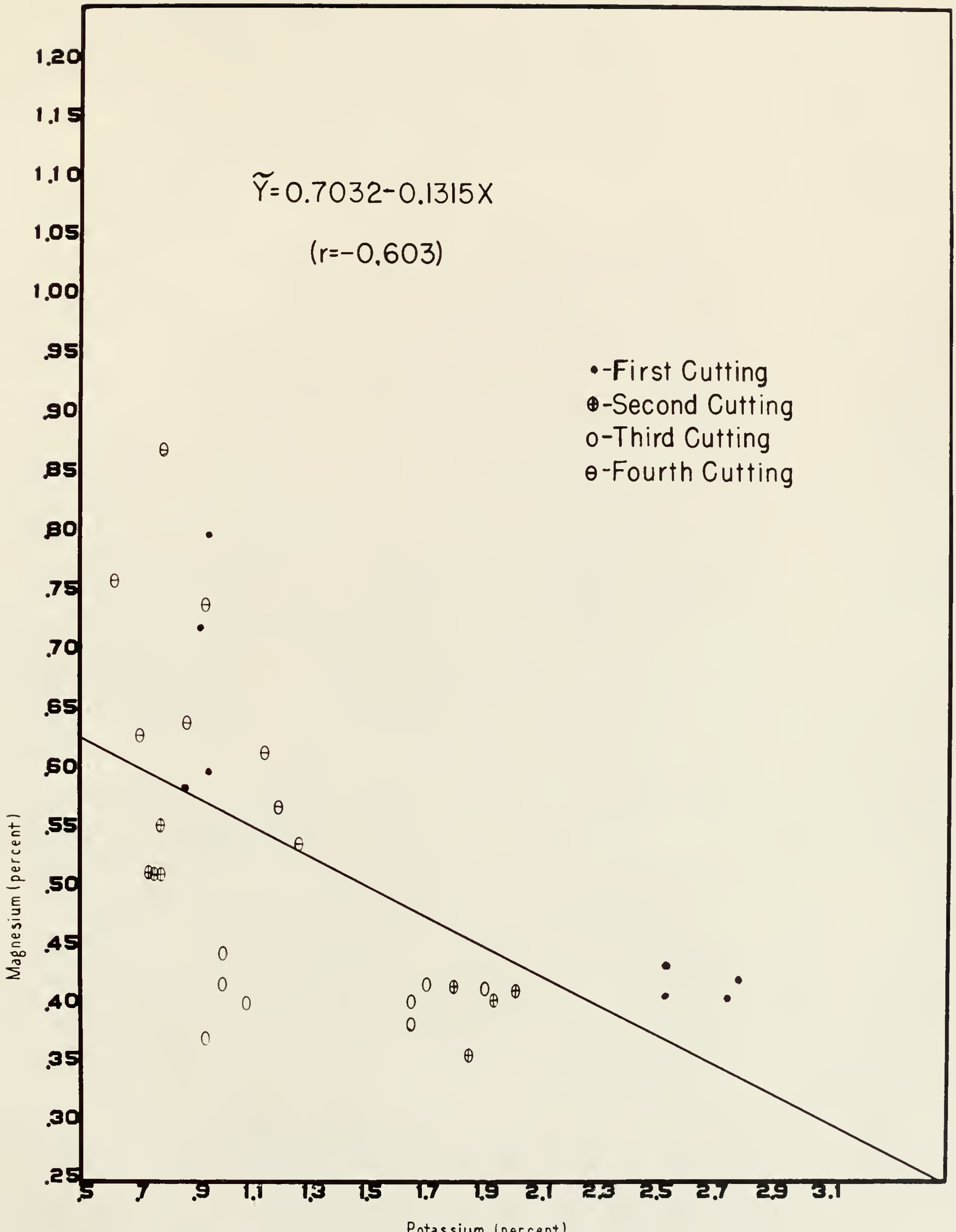

Fig. 12. Regression of magnesium content (Y) upon potassium content (X) for Soil V

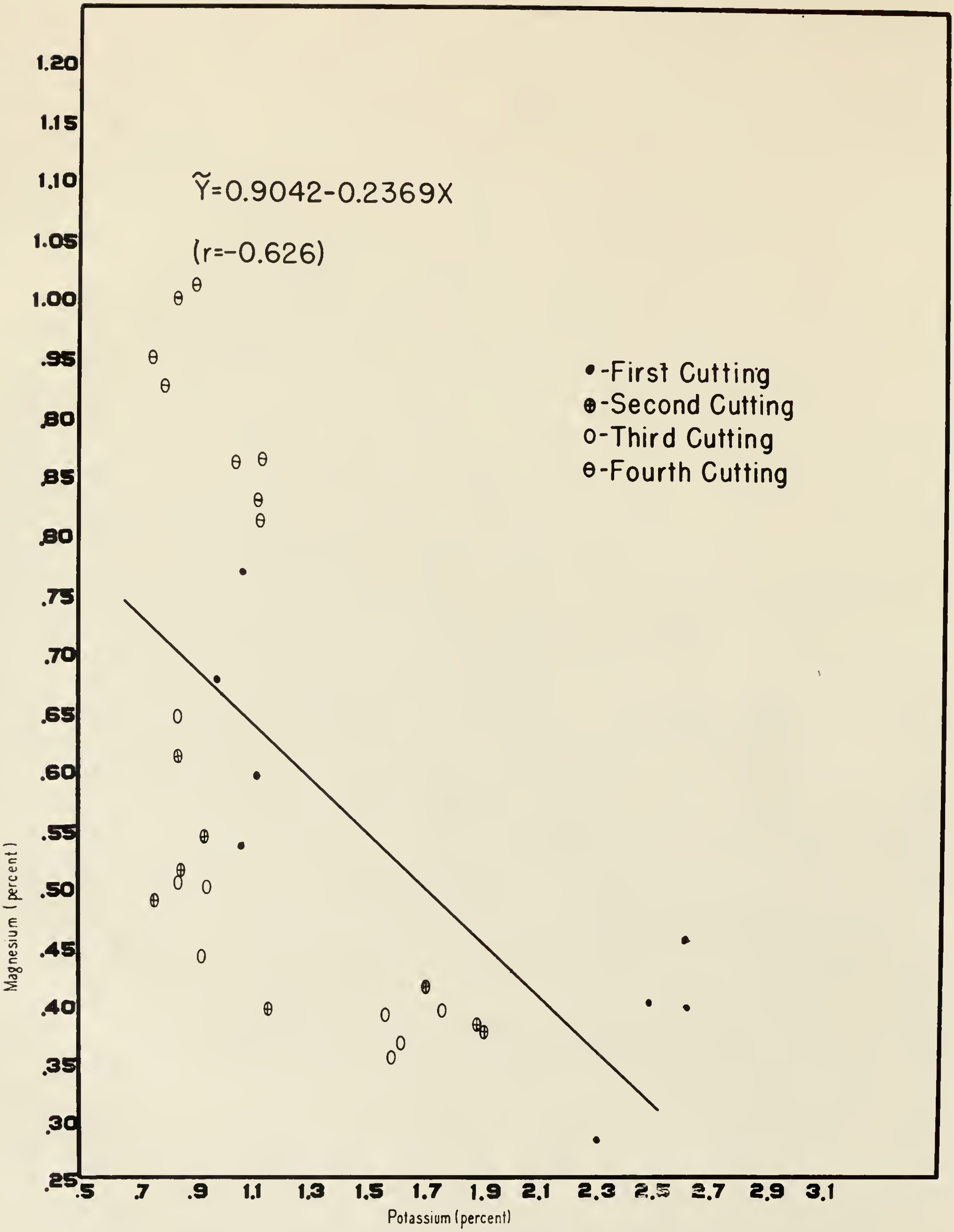

Fig. 13. Regression of magnesium content (Y) upon potassium content (X) for Soil VI

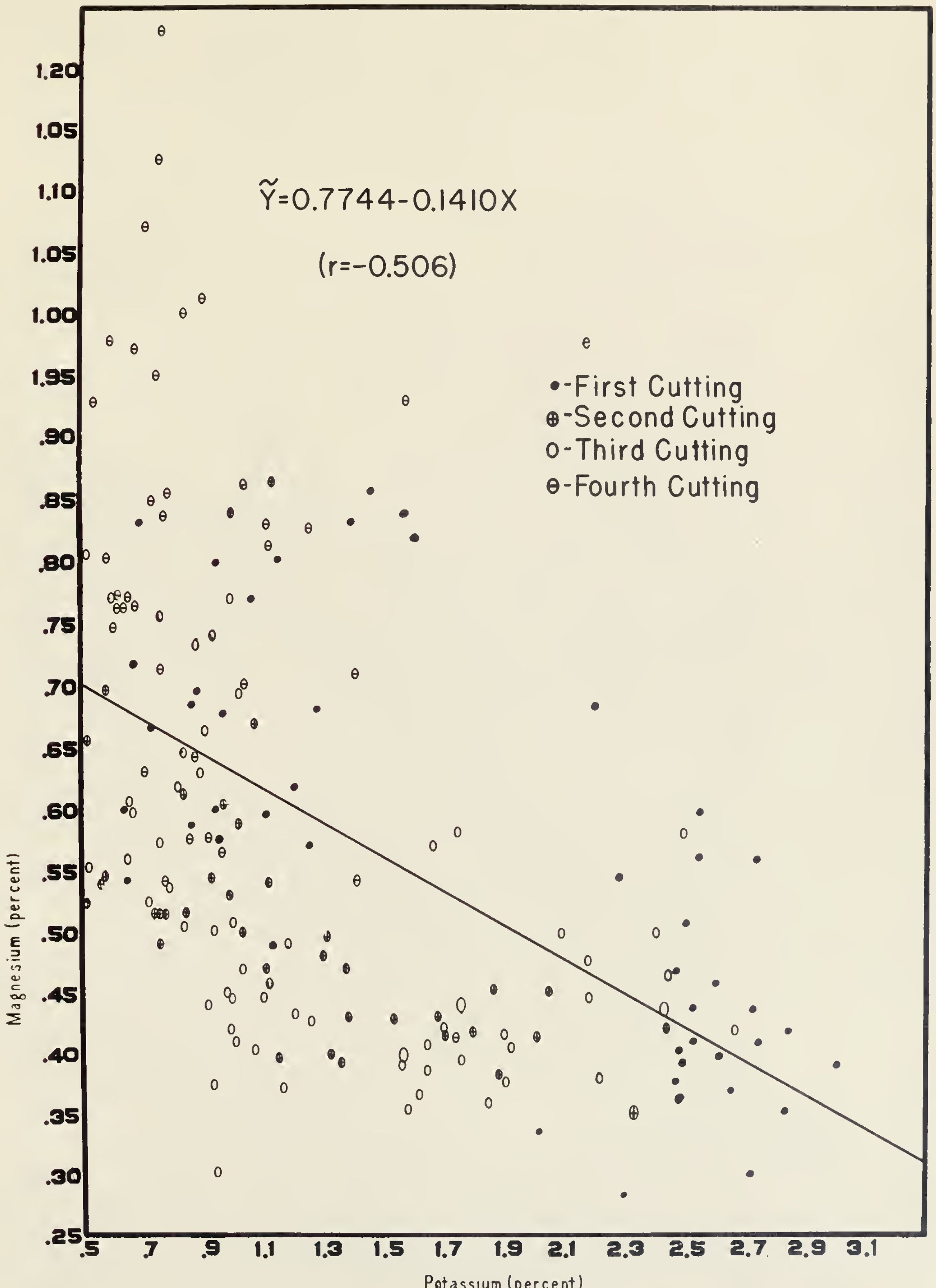

Fig.14. Regression of magnesium content (Y) upon potassium content (X) for all Soils

Analyses of Soil Materials

Analyses were made on samples of the original soil and samples of all soils after growing four crops of red clover. Table 57 shows the chemical properties determined on the original soils and the soils that received no treatment after growing the clover. Results shown are averages of duplicate samples and duplicate cultures.

The pH of Soil I changed from 5.08 to 6.38. This increase in pH is no doubt due to the effect of the calcium added in the form of $CaCO_3$. The pH of the other soils decreased due to the removal of large quantities of cations from the soil by the clover.

The total available phosphorus, 1:10 extraction, increased in all soils over the period of time between analyses. This was to be expected since a rather heavy application of phosphorus was made. All soils were low in available phosphorus at the beginning making it necessary to supply phosphorus so this element would not be limiting in the production of red clover. It is interesting to note that Soil III had a lower pH value and less available phosphorus than Soil IV. Soil III had received potassium in the field and had produced more alfalfa than Soil IV which removed more of the available phosphorus. Soil IV contained the most available phosphorus at the beginning and Soil I the least. Soil I still had the smallest amount of available phosphorus at the end of the experiment but Soil II contained the most. The greatest in-

Table 57. Properties of soil materials used in greenhouse experiment before and after growing four crops of red clover.

Soil No.	Type	pH		CHEMICAL PROPERTIES (ppm) Available P		Exchangeable K		Ca		Na		Mg		B		Exchange capacity me/100gm
		before	after	before	after	before	after	before	after	before	after	before	after	before	after	
I	Cherokee Clay loam (B horizon)	5.08	6.38	5.6	16.3	84	50	1012	1344	222	213	732	843	0.57	0.27	14.6
II	Summit silty clay loam	6.85	6.46	15.4	52.7	92	56	1622	1934	244	261	677	568	0.57	0.25	22.6
III	Parsons silt loam PK	6.11	5.45	16.0	44.5	65	35	1340	1416	32	80	238	175	0.75	0.27	15.9
IV	Parsons silt loam P	6.34	5.57	34.0	47.9	59	33	1392	1516	34	85	243	157	0.32	0.29	15.9
V	Cherokee silt loam P	6.97	6.51	17.2	43.1	69	38	1500	1492	40	85	235	180	0.39	0.14	15.1
VI	Cherokee silt loam PK	6.88	6.15	22.2	47.5	76	45	1378	1448	44	93	239	210	0.70	0.12	15.1

crease in available phosphorus content was observed in Soil II. The available phosphorus content of Soil II increased from 15.4 ppm to 52.7 ppm while the soil having the most available phosphorus at the beginning, Soil IV, only increased from 34 to 47.9 ppm. Slightly more clover was removed from Soil IV but not enough more to account for the difference in increase of available phosphorus in the two soils. With the decrease of pH of Soil II from 6.85 to only 6.46 more native soil phosphorus may have been made available or less applied phosphorus fixed or both. However, the pH of Soil IV decreased from 6.34 to 5.57 and under these circumstances more of the applied phosphorus may have been fixed.

Any mention made of the cations in the soils in the following discussion will refer to exchangeable cations. Soil II contained more exchangeable potassium than any of the other soils studied. Soil I which is a subsoil material and which came from the same general area as Soils V and VI was considerably higher in potassium than were these surface soils. The soils receiving applications of potash in the field, Soil III and VI, were higher in potassium both at the beginning of this study and at the close. The magnitude of this difference was greater in the case of Soils V and VI.

Calcium was contained in the phosphate compound applied to all soils and this fact helps explain why the calcium content of all soils except Soil V was higher at the close of the study. The difference between 1500 and 1492 ppm calcium in Soil V probably can not be considered a significant decrease, however. An increase in the calcium content of Soil I was expected since $CaCO_3$ was applied.

It is within the realm of possibility that enough sodium was released from some non-exchangeable form during the period of this study to result in an increase in this element. This is a possible explanation for the results noted in the case of all soils except Soil I and there was probably no real decrease in the sodium content of that soil. Sodium possibly may have been added in the distilled water as an impurity.

It is difficult to explain the fact that more exchangeable magnesium was present in the soil after growing the clover in the case of Soil I while the exchangeable magnesium content of the other soils was less at the close of the study. There seems to be two possible explanations for this. First, there may have been enough magnesium released from a non-exchangeable form to account for the increase. Second, the apparent increase shown may be a result of error. A fact of interest which may be pointed out is that more magnesium and sodium was present in Soils I and II than in any of the other soils studied. The Cherokee surface soils were considerably lower in magnesium than was the Cherokee subsoil.

For the normal growth of alfalfa, soils should contain 1.5 pounds, or more, per acre plow layer of available boron (3). Using this rule as a yardstick, Soils III and IV contained enough boron to support normal growth at the time the clover was planted. Soils III and IV contained the equivalent of 1.50 and 1.64 pounds per acre plow layer, respectively.

This is a borderline case and response might logically be expected. Results reported by Smith (24) indicated that there was no marked correlation between the amount of water soluble boron in soils and yield response on alfalfa. The water soluble boron found in these soils after growing the clover was less in all cases. From the analysis of the yield data it may be noted that there was no yield response to boron on any soil for the first cutting. There was no response for any cutting on Soils V and VI. Soil I was responsive for the second, third and fourth cuttings. Soil II showed a response for the third cutting. A decrease due to added boron was noted for the first cutting on Soil III while on Soil IV an increase due to boron was evident for the second cutting. There seems to be no correlation between the boron analytical method used and yield response.

The cation exchange capacity was also determined. Soil II had the greatest exchange capacity while there was little difference between those of the other soils. The exchange capacity of Soil I must be due largely to the inorganic colloid content since there was apparently little organic matter present. The surface soils from the same area, V and VI, contained less clay and apparently appreciable more organic matter. Soil II contained more clay and organic matter than Soils III, IV, V, and VI. The mechanical composition of these soils are given in Table 59.

Table 59. Mechanical composition of soil materials studied.

Soil	Physical Component Percent			Soil Class
	Sand	Silt	Clay	
I	27.6	36.4	36.0	Clay loam
II	15.0	55.0	30.0	Silty clay loam
III	23.2	58.4	18.4	Silt loam
V	24.0	52.0	24.0	Silt loam

Four phosphorus extraction performed on the original soils are summarized in Table 60. These results are averages of triplicate samples.

Table 60. Comparison of total available and adsorbed phosphorus test at various extraction ratios.

Method and Extraction ratio	Phosphorus (ppm)					
	Soil: I	Soil: II	Soil: III	Soil: IV	Soil: V	Soil VI
Total available - 1:10	5.6	15.4	16.0	34.0	17.2	22.2
Total available - 1:50	5.3	33.8	37.3	59.7	33.5	41.0
Adsorbed - 1:10	3.2	10.5	11.2	19.7	11.5	11.0
Adsorbed - 1:50	4.5	19.5	17.7	33.0	21.5	22.5

In all cases as much or more phosphorus was extracted from the soil by the 1:50 extraction. The amount of phosphorus removed by the 1:10 total available extracting ratio agrees rather closely with that removed by the 1:50 adsorbed extracting ratio. The degree of similarity apparently is greater in the case of Soils III, IV, and VI. As indicated by the data, about one-half to two-thirds of the total available phosphorus seems to be composed of the so called adsorbed phosphorus. A larger portion of the total available phosphorus of Soil I is made up of adsorbed phosphorus.

The effect of the applied chemicals on the chemical content of the soil after four cuttings were removed is shown by soils. The values given are means of the two duplicate cultures for each treatment.

Table 61. Chemical properties of Soil I after the removal of four cuttings of red clover.

Treatment	Exchangeable Cations in soil				Water Soluble	Total available	pH
	K ppm	Na ppm	Ca ppm	Mg ppm	B ppm	P ppm	
No	50.2	213.4	1344	843.3	0.27	16.3	6.38
K	62.4	210.4	1336	381.0	0.19	14.2	6.35
B	55.8	228.8	1312	994.7	0.74	10.7	6.20
Mg	48.6	225.8	1344	744.5	0.22	17.0	6.40
KB	62.8	255.6	1322	732.4	1.02	16.7	6.15
KMg	78.2	255.4	1310	885.6	0.18	14.4	6.30
BMg	53.4	221.8	1336	759.8	0.90	16.5	6.15
KBMg	56.4	239.4	1262	765.2	0.92	13.0	5.65

The potassium content of Soil I was greater in cultures receiving added potash even though more plant material was removed from these jars. An exception to this was the jar receiving the KMg treatment. The total yield from this treatment was the least for any treatment and the most potassium remained in the soil.

The most sodium remained in the cultures which received KB and KMg treatments. The reasons that more sodium remained in the culture which received the KB treatment are: (1) the boron compound added contained sodium and (2) potassium probably repressed the uptake of sodium by the plant so consequently more sodium was left in the soil. In the case of the KMg treatment less plant material was removed. This tends to remove less sodium and the potassium and magnesium probably both repressed the uptake of sodium by the plant. In the other treatments where boron was added there seemed to be slightly more sodium left in the soil.

There was no real differences in the calcium remaining in the soil due to the various treatments.

Less boron remained in the soil where this element was not applied. The quantity of boron remaining in the soil in the jars receiving no boron was lower than the critical low of 0.75 ppm proposed by Berger and Troug (3).

The lowest test value for available phosphorus was 10.7 ppm for the B treatment. More phosphorus may have been fixed in this soil. The relatively low values for the KBMg treatments probably are related to the high total yield of clover resulting from this treatment.

The greatest reduction in soil pH for Soil I is evidenced in the pH 5.65 of the soil from the KBMg treatment. More plant material was removed and consequently more cations were removed from this soil thus possibly decreasing the cation concentration.

The applications of potash to Soil II resulted in more potassium remaining in the soil after removing four crops of red clover except for the KBMg treatment.

Table 62. Chemical properties of Soil II after the removal of four cuttings of red clover.

Treatment	Exchangeable Cations in soil K ppm	Na ppm	Ca ppm	Mg ppm	Water soluble B ppm	Total available P ppm	pH
No	55.6	261.4	1934	567.7	0.25	52.7	6.46
K	73.2	269.6	1798	278.4	0.27	47.5	6.32
B	57.0	246.8	1824	244.4	0.72	48.8	6.33
Mg	56.8	247.4	1824	343.6	0.42	46.5	6.14
KB	63.8	283.2	1824	270.6	0.95	45.5	6.10
KMg	60.8	281.4	1778	653.2	0.24	45.9	6.07
BMg	51.2	255.2	1852	338.1	0.89	43.8	6.12
KBMg	56.4	296.0	1766	452.3	0.90	36.5	5.71

Considerably more clover was removed from the cultures receiving the KBMg treatments; therefore, more potassium should have been removed leaving less in the soil. It may be noted that more potassium remained in the soil as a result of the potassium treatment alone. The yield of clover was less as a result of this treatment than for any of the other treatments which included potassium on this soil.

More sodium remained in the soil when potassium was applied indicating that less sodium was removed by the plants. when the concentration of potassium was increased in the soil.

An explanation for the fact that the calcium content of the no treatment culture was higher lies in the fact that the total yield of clover was less from the culture. There is little if any difference among the other values.

The relatively high concentration of magnesium in the culture receiving the KMg treatment may be a result of magnesium released from non-exchangeable form as a result of potassium substitution. More magnesium was present, in general, when this element was supplied to the soil.

The same trend observed in Soil I is evident in Soil II with regard to boron remaining in the soil. More remained where boron had been applied to the soil.

Since there was less clover produced on the no treatment culture less phosphorus was removed. This left more in the soil as indicated in Table 62. Where the greatest amount of clover was removed less available phosphorus remained in the soil. This is the case for the KBMg treatment. This same type of reasoning applies to the pH of the soil. The lowest pH is 5.71 for the KBMg treatment while the highest pH is 6.46 for no treatment. Fewer and more cations were removed by the plants, respectively, effecting these results.

Again, in Soil III and IV more potassium was present in the soil when potassium was included in the treatment. Soils III and IV will be discussed together since there was more potassium remaining in the soil in all cases in Soil II than in Soil IV. This further indicates the effect of the potassium applied previously to Soil III in the field.

Again as in Soil II, more sodium remained in Soils III and IV when potash had been applied. In Soil IV there was more sodium remaining as a result of the boron addition. These data further indicate that exchangeable potassium in the soil serves to decrease the uptake of sodium by the plants.

Table 63. Chemical properties of Soil III and Soil IV after the removal of four crops of red clover.

Treatment	Exchangeable Cations in soil K	Na	Ca	Mg	Total available P	pH
	ppm					
Soil III						
No	35.0	80.0	1416	174.7	44.5	5.45
K	51.6	91.2	1334	200.0	39.8	5.36
B	35.8	72.0	1338	213.5	44.8	5.51
Mg	39.4	79.2	1406	217.5	46.0	5.60
KB	47.6	90.8	1368	205.5	41.0	5.50
KMg	51.6	84.8	1336	243.0	41.8	5.41
BMg	37.8	82.4	1392	236.1	44.8	5.57
KBMg	49.0	106.0	1324	244.5	41.1	5.47
Soil IV						
No	32.6	84.8	1516	156.9	47.9	5.57
K	43.0	95.6	1460	172.2	48.3	5.56
B	35.6	100.4	1486	179.3	55.0	5.82
Mg	28.4	84.8	1470	204.6	55.3	5.76
KB	42.0	114.0	1454	193.8	42.8	5.77
KMg	44.8	106.0	1412	187.1	49.5	5.71
BMg	30.0	85.6	1464	209.2	55.3	5.92
KBMg	48.8	104.0	1404	203.7	48.3	5.61

The data of Table 63 indicate that there was little if any real difference in the calcium content of Soil III due to the various treatments. The same was true for Soil IV. Soil IV was slightly higher in calcium than Soil III. Perhaps this is a result of previous crop growth on these two soils in the field. Larger crops were grown on Soil III since potash had been applied. There was more magnesium in Soils III and IV when magnesium was applied. The available phosphorus present in Soils III and IV after growing the red clover was directly related to the total quantity of plant material removed. Larger yields were obtained from the cultures having the least available phosphorus remaining. Soil IV contained more available phosphorus in each culture than did Soil III. The magnitude of this difference was not as great as that observed in the original soils. The degree of acidity increased in both soils to about the same extent. With exceptions the pH decreased when potash was applied.

In Soil V and VI added potassium produced the same effects as observed in the soils previously discussed. The KMg treatment of Soil VI appears to be an exception; however, the values for the other elements also appear low. One culture of this soil was destroyed in the greenhouse as a result of a hailstorm and the values obtained from the one saved do not appear to be reliable.

More exchangeable sodium remained in the soils receiving treatments of either potassium, boron or a combination of potassium and boron. This is to be expected since sodium was added in the sodium tetraborate and potassium added increased the amount of potassium removed by the plant and decreased the amount of sodium removed.

A relationship did exist between the yield of red clover and the amount of exchangeable calcium remaining in the soil. Less calcium remained when the yields were high. The amount of calcium remaining in Soil V was greater for all treatments than that in Soil VI.

Table 64. Chemical content of Soil V and Soil VI after four crops of red clover were removed.

Treatment	Exchangeable Cations in soil K	Na	Ca	Mg	Total available P	pH
	ppm					
Soil V						
No	38.0	85.2	1492	179.7	43.1	6.51
K	51.0	102.2	1518	218.3	35.4	6.42
B	30.4	92.8	1609	226.6	45.3	6.41
Mg	41.0	103.2	1600	225.7	44.7	6.53
KB	48.8	113.4	1550	222.8	41.4	6.60
KMg	49.6	124.0	1514	237.4	41.5	6.51
BMg	36.0	105.2	1536	247.3	42.4	6.65
KBMg	54.0	93.2	1518	260.6	43.0	6.62
Soil VI						
No	45.0	92.8	1448	210.4	47.5	6.15
K	57.6	103.2	1380	224.5	50.3	6.13
B	40.2	111.2	1460	209.2	45.5	6.26
Mg	41.6	91.2	1448	225.4	46.5	6.35
KB	55.0	121.2	1408	216.3	50.0	6.10
*KMg	30.4	80.0	1200	205.0	41.5	6.04
BMg	41.8	100.4	1460	272.0	50.5	6.37
KBMg	48.8	96.0	1416	244.8	47.8	6.13

* one sample only.

There was little variation in the amounts of magnesium contained in either of these two soils. The most magnesium in Soil V was contained in the cultures receiving the KMg, BMg, and KBMg treatments. More magnesium was removed from the soil having the magnesium treatment thus leaving about the same in the soil as remained in the case of some of the other treatments.

There is little variation in the available phosphorus content of Soil V as a result of the various treatments. Considerably more variation is evident in the case of Soil VI.

The pH values for all treatments of Soil V are greater than those for Soil VI. Since Soil VI had received potash in the field larger yields were obtained. These larger yields were accompanied by a more rapid removal of cations. This increased the H ion concentration and thus lowered the pH. The presence of less calcium in Soil VI is indicative of this fact.

A consideration was given to the percent of the exchange complex occupied by exchangeable magnesium. This was calculated on the equivalent basis. The results are summarized in Table 65.

Table 65. Percent of exchange capacity occupied by magnesium.

Soil	ppm	
	Before	After
I	41.7	48.0
II	24.9	21.0
III	12.4	9.1
IV	12.7	8.0
V	13.0	10.0
VI	13.2	11.6

Soils I and Soil II contained considerably greater percentage of exchangeable magnesium than did any of the other soils studied.

Release of Nonexchangeable Potassium. It is a generally accepted fact that soils release potassium from "fixed" forms. The potassium supplying power of soils varies considerably. It was shown in a recent study in Indiana that the potassium supplying power of the soil varied with soil type (6).

A study of the release of the nonexchangeable potassium from these soils may give some indication of the potassium supplying power of the soils of this area in Southeastern Kansas

The amount of nonexchangeable potassium removed was calculated by determining, first, the total amount of potassium removed from each culture of soil in the clover. The second step was to calculate the decrease in exchangeable potassium in the soil and subtract this value from the total potassium removed. The value obtained represented the nonexchangeable potassium that the plants were supplied by the soil. A summary of the nonexchangeable potassium released was made for each soil with respect to the treatments not including potassium.

Table 66. Nonexchangeable potassium released by each soil.

Treatment	Soil					
	I	II	III	IV	V	VI
	ppm					
No	84.6	90.3	71.6	63.0	103.1	113.5
B	98.9	128.9	51.7	73.7	93.6	109.0
Mg	95.4	114.9	68.0	54.6	113.1	103.1
BMg	96.1	117.0	64.1	57.5	105.1	118.4
Mean	93.74	112.75	63.86	62.20	103.88	111.00

The amount of exchangeable potassium removed from Soil I varies some as a result of treatments according to the data in Table 66. Apparently there was some relationship between the total yield of clover and the amount of fixed potassium released, the magnitude of the release depending upon the yields. More exchangeable potassium also was released from the other soils where the yield was highest.

Some of t hese soils had the ability to supply considerably more potassium than others. From the data in Table 66 indications are that Soil II released more exchangeable potassium than any other soil studied. The yields were smaller than those from Soil V or Soil VI which suggested that this soil had the greatest potassium supplying power. Soil III which received potash in the field released only a very little more than Soil IV. Soil VI which also had potash in the field supplied slightly more from nonexchangeable form than did Soil V. Soil I which was a subsoil belonging to the same series as Soils V and VI did not release as much fixed potassium; however, the total yields were not as great.

SUMMARY AND CONCLUSIONS

It was hoped that more information relative to the potassium, boron, and magnesium status of these soils might be gained by this experiment. The Cherokee silt loam is a soil generally considered to be of low productivity. The Cherokee subsoil is rather high in clay and presents a problem from the standpoint of its physical condition as well as chemical properties. Since some deep rooted crops feed partially in the subsoil it was thought that this soil would give some indication of the type of growth supported by these contacts. The Summit silty clay loam was selected because field experiments had been located on this soil type and some responses had been noted. The Parsons silt loam from the Thayer experiment field had shown nutrient deficiency symptoms in the field.

A greenhouse experiment was established treating each of these soils in duplicate with all possible combinations of chemicals supplying the elements potassium, boron, and magnesium. Uniform applications of ammonium nitrate and monocalcium phosphate were made in order to assure a sufficient quantity of nitrogen and phosphorus. Calcium carbonate was applied to the Cherokee subsoil. With this experiment employing the use of a complete factorial design it was possible by properly analyzing the data to single out the effects of any treatment or combination of treatments.

Four cuttings of red clover were removed from the cultures between March 12 and June 23, 1950. The plants were watered with distilled water at intervals.

Photographs were made at the time of the first harvest. The visual observations were not indicative of the yield response in the case of Soil IV. It is believed that tho variation between duplicates preventing significance was a result of two cultures having too much soil material to allow adequate watering.

The Cherokee subsoil gave a highly significant increase in yields due to the effects of potassium, boron, and the interaction of potassium and boron. A significant increase in yields resulted from the interaction of boron and magnesium. The Summit silty clay loam was shown to be a responsive soil by the fact that a highly significant increase in yields resulted from the effects of potassium, boron, and magnesium used alone and the interaction of potassium and boron. The physical condition of the two soils just discussed was rather poor. Highly significant increases in yields were effected by the addition of potassium alone on the four other soils belonging to the two soil types-Parsons silt loam and Cherokee silt loam. A significant decrease in yield was detected on the Cherokee silt loam, Soil V.

From the chemical analyses of the plant material it was observed that the addition of potassium and boron increased the potassium and boron content of the plant material. The addition of magnesium increased the magnesium content of the red clover when applied alone or with boron but not when in combination with potassium. Indications were that the yield response to potassium was somewhat related to the percentage composition of the plant material with respect to potassium. The actual percentage varied slightly with soils but appeared to fail within the range of 0.9-1.1 percent potassium. The boron content of the plant material from the Cherokee subsoil was indicative of its deficiency of boron. The magnesium content of the clover was greater for the low yielding fourth cutting when the potassium content was lowest.

By a statistical correlation the phosphorus and magnesium uptakes were shown to be related. Magnesium additions served to increase the phosphorus content of the plant when magnesium was taken up in larger quantities. The positive correlation was significant for the soils as a whole and for all of the soils individually except for the Cherokee subsoil. Thus the contention that magnesium acts as a carrier of phosphorus in the plant was supported.

A highly significant negative correlation was established between potassium and magnesium uptake. Thus the uptake of magnesium and consequently phosphorus may be repressed by high concentrations of potassium in the soil.

Some chemical properties of the soils were determined both before and after growing the clover. Measurements made were of soil pH, available boron, total available phosphorus, and for exchangeable sodium, exchangeable magnesium, exchangeable calcium, and exchangeable potassium. The Cherokee subsoil was the only soil needing lime as indicated by the pH. The soils were rather low in available phosphorus. The exchangeable potassium test indicated a moderate supply with the Cherokee subsoil containing the most. This suggests that deep rooted crops may be able to obtain part of their potassium supply from the subsoil in this area. Considerably less potassium was contained at the end of this study.

The decrease in exchangeable potassium supply does not account for all the potassium removed by cropping. The potassium utilized by plants which was not accounted for by the decrease in exchangeable potassium content was assumed to be released from the nonexchangeable form. The magnitude of this release varied with soil type, the Summit silty clay loam having the greatest potassium supplying power.

It seems difficult to place a value on this experiment so far as practical field recommendations are concerned. This study may serve to furnish or supplyment the present knowledge with basic facts concenring these soils. The actual response occurring in the greenhouse may not occur in the field. An experiment of this type imposes rather intensive cropping on the soil. The total yields obtained during this short period were equal to about 10 to 20 tons air dry weight of red clover per acre. This would be equal to at least five years of successive cropping.

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THE EFFECT OF MAGNESIUM, BORON, AND POTASSIUM ON THE GROWTH AND CHEMICAL COMPOSITION OF RED CLOVER GROWN ON CERTAIN SOILS OF THE CLAYPAN GROUP

by

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Investigations conducted in the Southeastern Kansas area have indicated the need for potassium and in some cases for boron, also. Little evidence has been presented regarding the need of these soils for additional magnesium. The effect of the application of these elements on the yield of red clover was studied in the greenhouse. Chemical analyses of the plant material were made in the laboratory to ascertain the influence of the applied chemicals upon the uptake of these and other elements by the plant. The soils were analyzed both before and after cropping in order to determine the influence of continuous cropping and applied chemicals on the chemical composition of these soils.

Four cuttings of red clover were removed from the soils studied between the dates of March 12 and June 23, 1950. The total yields were in the proportion of 10 to 20 tons of air dry plant material per acre. When a study was made of the analyses of variance of the yield data, it was found that significant responses due to treatments were obtained from all soils. The Cherokee subsoil showed a highly significant yield response for the last three cuttings. A highly significant yield response resulted from potassium, boron, and the interaction of potassium and boron. A significant increase was noted as a result of the interaction of boron and magnesium.

The Summit silty clay loam was shown to be a responsive soil by the fact that a highly significant increase in yields resulted from the effects of the potassium, boron, magnesium, and interaction of potassium and boron. Both soils studied belonging to the soil type Parsons silt loam gave an over all response to potassium that was highly significant. The two soils studied of the soil type Cherokee silt loam showed a highly significant increase in yields from the potassium treatment. A significant decrease in yields resulted from the interaction of potassium and magnesium.

The analyses of the red clover showed that where potassium or boron was applied to the soil the plant material grown on these soils was higher in these elements. Where magnesium was applied the red clover contained more magnesium unless it was applied in combination with potassium. The potassium content of the plant material decreased with cutting. The low boron content of the red clover grown on the Cherokee subsoil was indicative of the boron deficiency of that soil. The relationship between the uptake of magnesium and phosphorus was studied. The positive regression of the magnesium content upon the phosphorus content was shown to be highly significant for the soils belonging to the soil types Parsons silt loam and Cherokee silt loam. It was significant for the Summit silty clay loam. There was no significance noted for the Cherokee subsoil which was rather high in exchangeable magnesium. The negative regression of the potassium content upon the magnesium content of the plant material was highly significant for all soils.

Analyses of the soil materials were made before and after growing the red clover. The determinations that were made were for pH, lime requirement, total available phosphorus, exchangeable potassium, exchangeable calcium, exchangeable sodium, exchangeable magnesium, and water soluble boron.

The supply of exchangeable potassium in the soil materials was not as great after growing the red clover as when the study began. The amount of potassium removed by the clover was greater than the decrease in soil test values would indicate. The quantity of potassium removed by the plants more than that accounted for by the decrease in exchangeable potassium in the soils was assumed to have been released from non exchangeable form.

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