To the Graduate Council:

I am submitting herewith a thesis written by Horace C. Smith, Jr. entitled "Magnesium Status of Tennessee Soils." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Lloyd F. Seatz
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and recommend its acceptance:

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MAGNESIUM STATUS OF TENNESSEE SOILS

A THESIS

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

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by

Horace C. Smith, Jr.

August 1952

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to:

The International Minerals and Chemical Corporation for providing funds for this study;

Dr. Eric Winters for suggesting and directing this study;

Dr. L. F. Seatz for reviewing this thesis, and

Mr. William Bishop for assisting in collecting the soil samples.

Horace C. Smith, Jr.

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CHAPTER I

INTRODUCTION

Magnesium is one of the essential elements for the growth of all plants, since it is the key metallic ion in the chlorophyll molecule. Magnesium deficiency in the plant often results in interveinal chlorosis of the leaves, but the symptoms caused by a deficiency will vary with the species. The chlorosis usually begins at the edges of the leaves and gradually spreads toward the center with increasing intensity of the deficiency. The older leaves are affected first and, in severe cases, they may lose all of their green color, while the younger leaves develop some chlorosis.

Reports of magnesium deficiency symptoms have been received only in the past few years in Tennessee. Deficiency symptoms similar to those described for magnesium deficiency in corn, tobacco, and vegetable crops have been observed on the Cumberland Plateau. Similar symptoms have been seen in corn on the Highland Rim, in the Central Basin, and in the southern portion of West Tennessee. Magnesium deficiency symptoms of cotton on the Highland Rim and in West Tennessee have been reported.

A study of a limited number of soils during 1948 and 1949 (6)[1] indicated that magnesium deficiency symptoms of corn and tobacco were associated with either a low level of exchangeable magnesium in the

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[1]Numbers in Parenthesis refer to literature cited.

soil, or a wide calcium-magnesium ratio and/or a wide potassium-magnesium ratio. A general picture of the magnesium status of the soils in the various regions of Tennessee would be helpful to research personnel in planning their fertility experimentation and to educational agencies in making fertilization and liming recommendations.

CHAPTER II

REVIEW OF LITERATURE

Magnesium has long been recognized by plant physiologists as belonging to the group of chemical elements indispensable for normal plant growth. It is only within the last 30 years, however, that this element has been recognized as having any major significance in practical fertilizer usage. The first paper pointing out its importance to field crop production was published in 1922 (18), and a more detailed account followed in 1923 (19). These papers discussed magnesium deficiency symptoms of tobacco plants growing on sandy, acid soils of North Carolina. The addition of magnesium salts was found to correct a chlorotic condition of the tobacco, observed as early as 1912, when the addition of nitrogen, phosphorus, and potassium failed to correct the condition. This chlorosis of tobacco has since been observed in a number of states. McMurtrey (28) has summarized the effects of magnesium on the growth and composition of tobacco.

Jones (23) reported in 1929 that a chlorosis of corn could be corrected by magnesium fertilization. In 1930, Chucka and Brown (14) showed that increases in the yield of potatoes could be obtained when the crop was fertilized or sprayed with magnesium salts. Magnesium deficiency symptoms of soybeans were reported in 1930 (15) and in cotton in 1932 (15). Since these early dates many investigators have reported magnesium deficiency symptoms and responses to magnesium fertilization on a wide variety of crops. Beaumont and Snell (7) investigated the

effects of low magnesium levels on seventeen crops. They found buckwheat, spinach, turnips, corn and tobacco to be most affected; the small grains, grasses, clover, and potatoes to be only slightly affected and other crops to be unaffected. Boynton (10) has reviewed the problem of magnesium nutrition of apple trees; Camp (12) and Fudge (17) the use of magnesium in citrus fertilization; and Carolus and Brown (13) the magnesium problem in vegetable production.

Most of the reports of magnesium deficiencies have come from areas in the Coastal Plain region along the Gulf of Mexico and Atlantic Ocean. New Jersey research workers (4, 5, 38) have found that many of the soils of the Coastal Plains are naturally lacking in magnesium minerals. The sandy soils of this region are also subject to serious losses of the element through the leaching action of the heavy rainfall of the area. Bear et al. (5), in a study of twenty New Jersey soils, found the virgin Coastal Plain soils contained from 400 to 7,400 pounds of total magnesium and from 24 to 267 pounds of exchange magnesium. The soils of the Appalachian Province contained from 7,000 to 23,400 pounds of total magnesium and 77 to 1,225 pounds of exchange magnesium.

Bear and Prince (4) estimate that on the average about one-fourth of one per cent of the total magnesium in the New Jersey soils becomes available annually; however, the rate of release from each soil differed considerably. They found no definite relationship between the total magnesium in soils and the amount in the exchange complex.

Peach (36) found that many of the virgin Norfolk light sands of Florida had about 10 pounds or less of exchangeable plus soluble

magnesium. The Summaries of North Carolina Soil Tests Results (35) indicate that the soils of the Coastal Plain region of that state are much lower in magnesium than the Piedmont and Mountain areas. The Soil Conservation Service has reported (13) that the drainage waters of the Coastal Plain have one to three parts per million of magnesium while Tennessee, Kentucky, Western Virginia, Pennsylvania, and New York waters have four to nine ppm. and those of the midwestern states have ten to twenty ppm. Beeson (8) has prepared a generalized map of the occurrence of magnesium deficiency in plants. This map indicates that the major problems occur in the Coastal Plain region and in the northeastern states. Most of these deficiencies have occurred in vegetables, tobacco, potatoes and cotton.

Magnesium deficiency is not confined to the Coastal Plain and northeastern states, however, since a few reports are found in the literature from other areas. Albrecht et al. (1) have reported plant symptoms indicating magnesium deficiencies in Missouri. They have also made a survey of the magnesium levels in different regions of the state; and found that the area with the highest magnesium content did not have as much as 240 pounds of available magnesium per acre. This value was considered to be medium in amount. The mean for 600 samples was 168 pounds with the lowest levels occurring in the southern areas of the state. Some soils in other areas are naturally low in magnesium, others have become or may become low because of the long time removal of crops, particularly those fertilized with elements other than magnesium. Magnesium problems occur in some areas following the use of high

calcium liming materials or heavy application of potash.

The three basic cations, potassium, calcium, and magnesium compose the largest portion of the essential nutrient elements found in plant ash. Bear and associates (14), Lucas et al. (25) and others have shown from analyses of plants grown in soils or other mediums with widely varying supplies of potassium, calcium and magnesium that their sum, on a chemical equivalent basis, tends to be constant if a specific variety of the plant is grown under uniform environmental conditions except as to the supply of these cations. Soil-plant literature contains many examples of interrelationships between cations in soils and plants. These investigations indicate that the absolute amounts of available calcium, potassium and magnesium as well as their relative values, are important in soils to the nutrition of plants.

As early as 1901, Loew (24) formulated his theory of the "lime factor" for plants. This theory postulated that for best results plants require a fairly definite ratio between calcium and magnesium in the soil. Loew was of the opinion that the ratio should be greater than two to one or toxicity would result. This theory prompted much discussion and research. The investigations by Moser (33) and others have led to the conclusion that there is no definite optimum calcium-magnesium ratio. However, research has shown that any extreme lack of balance between these cations may decrease the magnesium content of plants and decrease yields.

In the early work with tobacco "sanddrown", Williams and Mathews (44) found that calcite made the magnesium deficiency worse.

MacIntire (27) also pointed out that calcitic limestone may aggravate magnesium deficiency symptoms of plants grown on certain soils. Hunter (22) reported that the weight of alfalfa was not significantly affected by variations from 4:1 to 32:1 in the soil calcium-magnesium ratio; however, the per cent of magnesium in the plants increased as the ratio decreased. Bear and associates (4) reported that magnesium deficiency may be induced by heavy application of calcitic limestone, particularly with shallow rooted crops.

Naftel (34) grew sorghum in pots containing Hartsells fine sandy loam with varying amounts of calcium. He reported that the magnesium content of the plants decreased and the calcium increased as the per cent calcium saturation was increased by calcium carbonate additions. When the per cent calcium saturation was increased by the addition of a mixture of calcium and magnesium carbonate the per cent magnesium in the plants increased and the calcium decreased slightly.

Mehlich and Reed (31) and others have reported that increasing the calcium to magnesium ratio in the soil increased the ratio of these elements in the plants; however, the ratios in the plants were different from those in the soil. Mehlich and Reed (30) have also used average "c Mg" values (ratio of Ca:Mg in the soil to Ca: Mg in the plant) to compute the Ca: Mg ratio in a soil needed to obtain average Ca:Mg in various crops. The computed soil Ca:Mg ratios were found to be 6:1 for turnips, red clover, alsike clover, and oats; 5:1 for alfalfa, cotton and timothy; and 4:1 for soybeans.

Beasley (6), in his study of magnesium deficiencies in Tennessee, found that there was no definite calcium to magnesium ratio at which

magnesium deficiency symptoms would occur in corn. He found the maximum ratio at which there were no deficiency symptoms to be 10.4:1, while the minimum ratio at which there were deficiency symptoms was 2.6:1. Beasley's data also indicated that crops may be able to tolerate wider ratios of calcium to magnesium as the quantity of available magnesium increases.

Potassium seems to be the most competitive cation in the potassium, calcium and magnesium group. Van Itallie (42) found that the replacing or competitive abilities of these cations was in the order of potassium, magnesium, and calcium. Lundegardh (26) concluded from his investigations that the substitution of cations is strongest between the outer most ions of the series: manganese, calcium, magnesium, potassium, and sodium. Wilson (45) and others have shown that the order of the rate of removal of cations from soils by electrodialyses is potassium, calcium, and magnesium; and that plants tend to absorb the three cations in that order.

Prince and associates (38) have suggested that the most important single factor influencing the uptake of magnesium by plants is the quantity of available potassium. They also attribute a large per cent of the magnesium deficiencies in New Jersey to heavy applications of potash fertilizers. Boynton and Burrell (11) induced magnesium deficiency symptoms in apple leaves by heavy potash fertilization. Bower and Pierre (9) reported that potassium fertilization decreased the magnesium content of seven different crops. Stanford et al. (40) and Lucas et al. (25) have reported a reciprocal relationship between

calcium and magnesium to the potassium in plants.

Beasley (6) also found that magnesium deficiency symptoms occurred at varying potassium to magnesium ratios. No normal corn plants were seen where the ratio in the soil was greater than 1:2; however, there were many plants showing deficiency symptoms where the ratio was less than 1:2.

The optimum ratios of magnesium, calcium, and potassium in the soil for plants is no doubt dependent on the cation exchange capacity of the soil and the per cent saturation of each cation. Mehlich and Reed (31) have shown that at constant magnesium levels in a soil, magnesium in plants increases with decreasing exchange capacity. Embelton and Boynton (16) have suggested that the relationship between magnesium and potassium is as important as absolute amounts in soils of low exchange capacity. Mehlich and Reed (29) found that increasing the soil potassium saturation reduced the absorption of magnesium by cotton plants more at lower calcium saturation than at higher soil calcium saturation. Bear and associates (5), from their extensive investigations of cation equilibria, have suggested that the exchange complex of the "ideal soil" should be occupied by twenty per cent hydrogen, sixty-five per cent calcium, ten per cent magnesium, and five per cent potassium on an equivalent basis.

Virgin soils are usually depleted of essential elements after many years of cultivation unless fertilizers are added. It would be expected that magnesium would follow this pattern. Ames and Schollenberger (2) made a study of a large number of virgin and cultivated soils

in Ohio. They found that virgin surface soils contained more magnesium than the cultivated surface soils; however, the subsoils of the cultivated areas contained more magnesium than the virgin subsoils. They also found that both virgin and cultivated soils had more total and soluble magnesium in the subsoil than in the surface soil. Auten's data (3), from a study of northern forest soils and adjacent cultivated fields, support the findings of Ames and Schollenberger.

Albrecht and associates (1) have concluded that good soil management such as the use of sod crops with fertilization and liming, increase the nitrogen, organic matter, and calcium levels in a soil but decrease the magnesium saturation. They found that fallowing and other poor management practices increased the exchangeable magnesium in the surface soil by bringing up the lower profile.

Mehring (32), in his summary of magnesium in fertilizers, lime, and manure, reported that the interest in adding magnesium carrying materials to mixed fertilizers has increased in recent years because of the discovery of the need of magnesium for tobacco in 1922 and other crops since that time; the decrease in use of organic materials and kainite; the increased interest in neutral fertilizer; and the use of other material to displace sand as a filler. Mehring found, however, that the average mixed fertilizer in 1945 contained only 2.07 per cent magnesium oxide compared to 2.28 per cent in 1910. He estimated that in 1946, 65 per cent of all magnesium oxide added to the soils of the United States was from liming materials, about 6 per cent from fertilizers, 28 per cent from manure, and about 1 per cent from miscellaneous sources.

Skinner and Associates (39) compared standard and concentrated fertilizers in Virginia, North Carolina, South Carolina, and Georgia in a number of experiments. They found high analysis fertilizers did not give as high a yield as low analysis fertilizers unless magnesium was added. Volk, et al. (43) reported that magnesium in some form was a necessary supplement to high analysis fertilizers for cotton grown on soils with only 0.1 to 0.2 milliequivalents of exchangeable magnesium.

Bear and associates (5) suggest that at least 40 pounds of magnesium oxide per acre should be applied annually to crops in magnesium deficient acreas. They point out that this should be in a soluble form for acid-soil crops on sandy soils. They recommend that high magnesium limestone be used on high exchange capacity soils for crops which grow best at pH 6.0 to 6.5.

CHAPTER III

MATERIALS AND METHODS

The soil samples used in this survey were obtained from several sources. Most of them were obtained by selecting every tenth sample received at the Tennessee State Soil Testing Laboratory. A few soil samples were received from agricultural workers who had observed magnesium deficiency in crops. Others were collected by the writer from experimental and farmers' fields.

The following determinations were made on all samples: exchangeable magnesium, calcium and potassium, and pH. The exchangeable cations were determined by the rapid chemical tests described by Peech and English (36) with modifications, as proposed by Beasley (6). Detailed analytical procedures are given in the Appendix. These procedures are known to be less accurate than the standard methods; however, the simplicity, rapidity, and moderate accuracy of the tests make them suitable for a survey of this kind. Duplicate determinations were found to check within the following limits: magnesium, 20 pounds per acre; calcium, 100 pounds at the low and medium levels and 200 pounds at the high levels; and potassium, 10 to 20 pounds. The calcium and potassium content of the soil extracts was also determined by the flame photometric method described by Toth and Prince (41). There was excellent agreement between the rapid chemical and flame methods.

The pH of the samples was determined with a Beckman potentiometer equipped with a glass electrode. The soil-water ratio was adjusted to give a thin paste (approximately 1:1).

Plant tissue samples were collected from several species of plants for a determination of their cation content. The ashing method, as proposed by Gieseking et al. (20), was used to oxidize the organic matter in the tissue samples and to bring the salts into solution. The same procedures were followed for the determination of calcium, magnesium, and potassium in the tissue extracts as for the soil extracts.

CHAPTER IV

PRESENTATION OF DATA

In order to evaluate the magnesium status of the soils of Tennessee, this study was divided into several phases: (1) a survey of the exchangeable magnesium in soils of the major physiographical regions of the state; (2) a comparison of the amounts of exchangeable calcium and potassium to the magnesium in those soils; (3) a study of the cation levels and ratios in certain crops and soils and their relation to magnesium deficiency symptoms; and (4) investigation of the relation between the application of various liming materials and the amount of exchangeable magnesium and calcium in soils.

Four hundred and ninety-one surface soil samples were obtained from several counties in five regions of the state for the general survey. These regions were: the Cumberland Plateau, the Highland Rim, the Central Basin, the East Tennessee Valley, and West Tennessee. The parent rock and material from which the soils were developed varies a great deal within each region; however, the variation in the parent material between regions is greater than that within regions. In addition to the soil samples used in this survey, other samples were collected from the Cumberland Plateau and West Tennessee for more specific studies.

Cumberland Plateau

The soils of the Cumberland Plateau were derived from sandstone and sandy shale. They are, in general, low in plant nutrients, very

strongly acid, low in cation-exchange capacity, and rather shallow. Some of the sandy soils of this area have profiles similar to the magnesium deficient soils of the Coastal Plain. Rather heavy fertilizer and lime applications are required to produce high crop yields.

Certain data from six surface and subsoil samples collected from woodland areas on the Plateau are presented in Table I. These data indicate that the virgin soils of the region have low pH values and are low in calcium, magnesium and potassium. The exchangeable calcium was lower in the subsoils than in the surface soils, while the magnesium was higher in the subsoils. The Ca:Mg ratios of the subsoils are, therefore, narrower than those of the surface soils. Since the potassium in the two horizons of each soil varies less than the magnesium, the K:Mg ratios are narrower in the subsoils.

The pH, exchangeable cations, and cation ratios of 62 soil samples obtained from cultivated fields in Cumberland Plateau counties are shown in Table II. The amount of magnesium in these soils varied considerably, sample number 36 containing only 0.05 me. and sample number 33 having 0.53 me. per 100 grams of soil. The average amount of magnesium in these samples was 0.24 me. Examination of the data shows that 43.5 per cent of the samples tested very low (0.04 to 0.21 me.), 37.1 per cent low (0.21 to 0.41 me.), 19.4 per cent medium (0.41 to 0. 82 me.), and no sample contained enough magnesium to test high (above 0.82 me.). The magnesium levels in these soils are of the same general order as those found in the sandy soils of other areas (4,5,37).

There have been more reports of magnesium deficiency symptoms from this area than from other sections of the state. Beasley (6)

TABLE I

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE AND SUBSOIL SAMPLES COLLECTED FROM WOODLAND AREAS ON THE CUMBERLAND PLATEAU

Soil No.	Horizons	pH	Milliequivalents[a] of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
1	Surface Soil	5.4	1.10	0.08	0.13	13.7	1.63
	Subsoil	5.0	0.87	0.19	0.13	4.5	0.68
2	Surface Soil	4.8	0.63	0.08	0.14	7.8	1.75
	Subsoil	4.7	0.50	0.22	0.16	2.2	0.73
3	Surface Soil	5.0	0.63	0.12	0.10	5.2	0.83
	Subsoil	4.6	0.38	0.25	0.06	1.5	0.24
4	Surface Soil	5.2	0.95	0.10	0.12	9.5	1.20
	Subsoil	5.0	0.80	0.15	0.07	5.3	0.47
5	Surface Soil	4.9	0.76	0.10	0.10	7.6	1.00
	Subsoil	4.7	0.42	0.19	0.08	2.2	0.42

[a] Milliequivalents per 100 grams of soil; 1.0 me. equivalent to 400 pounds of calcium, 243 pounds of magnesium, or 781 pounds of potassium per two million pounds of soil.

TABLE II

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE CUMBERLAND PLATEAU

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
1	Claiborne	5.5	2.2	0.39	0.15	5.6	0.38
2	Cumberland	6.5	5.5	0.25	0.15	22.0	0.60
3	"	7.2	5.5	0.16	0.07	34.3	0.44
4	"	5.7	2.4	0.10	0.12	24.0	1.20
5	"	6.3	4.5	0.12	0.12	37.5	1.00
6	"	6.5	5.0	0.12	0.17	41.6	1.42
7	"	6.3	5.0	0.12	0.19	41.6	1.58
8	"	5.5	2.1	0.12	0.15	17.5	1.25
9	"	5.3	2.1	0.19	0.15	11.0	0.79
10	"	6.3	4.0	0.17	0.14	23.5	0.82
11	"	4.6	0.6	0.08	0.18	7.8	2.25
12	"	4.4	0.6	0.08	0.15	7.8	1.87
13	"	4.1	0.5	0.08	0.13	6.2	1.63
14	"	6.0	3.0	0.21	0.22	14.2	1.05
15	"	5.9	3.6	0.25	0.29	14.4	1.16
16	"	5.6	3.2	0.19	0.29	16.8	1.52
17	"	5.9	5.0	0.29	0.28	17.2	0.97
18	"	5.2	1.5	0.14	0.22	10.7	1.57
19	"	5.3	1.6	0.25	0.19	6.4	0.76
20	"	5.4	2.2	0.45	0.23	4.8	0.62
21	"	5.4	2.3	0.41	0.28	5.6	0.68
22	"	5.5	2.2	0.19	0.28	11.5	1.47
23	"	5.6	3.6	0.19	0.28	18.9	1.47
24	"	5.4	3.2	0.27	0.14	11.8	0.52
25	"	5.7	3.7	0.31	0.23	11.9	0.74
26	"	5.5	1.7	0.16	0.28	10.6	1.75
27	"	5.2	1.0	0.21	0.20	4.7	0.95
28	"	6.0	2.6	0.10	0.17	26.0	1.70
29	"	5.9	3.7	0.19	0.29	19.4	1.53
30	"	5.5	3.1	0.12	0.22	25.8	1.83
31	"	5.9	3.7	0.31	0.27	11.9	0.87
32	Fentress	6.7	5.2	0.06	0.12	86.6	2.00
33	Grundy	6.0	2.5	0.53	0.27	4.7	0.51
34	"	5.9	5.2	0.14	0.22	37.1	1.57
35	Hamilton	5.2	3.0	0.27	0.13	11.1	0.48
36	Hancock	5.6	0.9	0.05	0.11	17.4	2.20
37	Marion	6.3	2.7	0.16	0.09	16.8	0.56
38	Overton	6.9	5.2	0.41	0.20	12.6	0.49
39	"	6.3	3.2	0.25	0.05	12.8	0.20
40	"	6.7	7.5	0.12	0.15	62.5	1.25

TABLE II (continued)

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE CUMBERLAND PLATEAU

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
41	Overton	6.3	3.2	0.19	0.14	16.8	0.74
42	"	7.2	7.5	0.19	0.12	39.4	0.63
43	"	5.9	3.7	0.29	0.28	12.7	0.97
44	"	6.4	3.7	0.23	0.15	16.0	0.65
45	Pickett	6.1	5.2	0.41	0.20	12.6	0.49
46	Putnam	7.5	7.5	0.37	0.38	20.2	1.03
47	"	6.4	3.8	0.25	0.28	15.2	1.12
48	"	6.4	3.8	0.47	0.29	8.0	0.62
49	"	7.0	7.5	0.47	0.14	15.9	0.30
50	"	7.4	5.5	0.14	0.09	39.2	0.64
51	Rhea	6.1	8.5	0.21	0.08	40.4	0.38
52	Warren	5.6	5.5	0.29	0.20	18.9	0.69
53	"	6.0	3.1	0.41	0.17	7.5	0.41
54	"	5.8	2.1	0.25	0.14	8.4	0.56
55	"	6.5	5.2	0.35	0.27	14.8	0.77
56	"	5.8	2.2	0.37	0.15	5.9	0.41
57	"	7.0	6.5	0.49	0.31	13.2	0.63
58	"	7.3	6.0	0.25	0.15	24.0	0.60
59	"	6.6	4.0	0.08	0.10	50.0	1.25
60	White	5.8	1.3	0.41	0.17	3.1	0.41
61	"	6.3	3.5	0.43	0.26	8.1	0.60
62	"	5.9	2.2	0.31	0.13	7.1	0.42

analyzed soil samples from fifteen corn fields on the Plateau that showed magnesium deficiency symptoms. Fourteen of these soils contained less than 0.3 me. of exchangeable magnesium. Soils from two corn fields without deficiency symptoms contained 0.4 and 0.6 me. of magnesium. Beasley also found that the soils of six fields producing tobacco without deficiency symptoms contained from 0.49 to 0.88 me. of magnesium, whereas, the soils of six fields having plants with deficiency symptoms contained from 0.25 to 0.42 me.

The calculated cation ratios of the Plateau soils are included in Table II. The range of the Ca:Mg ratios was from 3.1:1 to 86.6:1, with an average of 15.4:1. Forty-seven of the 62 samples or 76 per cent had ratios greater than 10:1. The pH and calcium levels in many of these soils indicate they had been limed with calcite limestone; therefore, many of the wide Ca:Mg ratios are due to the relatively high exchangeable calcium content of the soils as well as to the low magnesium levels. The K:Mg ratios varied between 0.20 and 2.25, with a mean of 0.79. Fifty of the samples had ratios greater than 1:2 or 0.5.

Magnesium deficiency symptoms were observed in broccoli, sweet corn, dent corn, and snap beans on the Cumberland Plateau in 1950. Large areas of magnesium deficient plants were present in fields of normal plants. The broccoli and bean leaves of the affected plants were chlorotic between the veins as the crops approached maturity. The corn leaves showed the characteristic stripeing between the veins in the early stages of growth. The sweet corn continued to show this stripeing until maturity, whereas the younger leaves of the dent corn were normal in color. All of the fields had received rather large amounts of

calcitic limestone and mixed fertilizer. Composite samples of leaves from both normal and magnesium deficient plants were collected for analysis. Surface soil samples were also taken from the areas. Table III contains the cation values and ratios of these tissue and soil samples.

These data show that: (1) the magnesium was very low in all the soils, being somewhat lower in the soils producing magnesium deficient plants except the soil producing abnormal broccoli; (2) the exchangeable calcium was higher in the soils producing magnesium deficient plants except in the soil producing sweet corn; (3) the Ca:Mg and the K:Mg ratios were wide in all the soils, however, they were wider in the soils producing plants exhibiting magnesium deficiency symptoms; (4) although the sum of the cations in the leaves of the abnormal plants was approximately the same as that in the normal leaves, the magnesium in the plants with deficiency symptoms was lower than that in the normal leaves, while the calcium and potassium content was higher; (5) the Ca:Mg and K:Mg ratios, therefore, were wider in the magnesium-deficient leaves; and (6) the Ca:Mg ratios in the leaves were narrower than the ratios in the soils, whereas, the K:Mg ratios in the leaves were wider than those in the soils.

It has been suggested that the more soluble forms of magnesium should be applied annually to acid-soil crops growing on sandy, low exchange capacity soils or to crops growing on soils high in calcium and potassium in magnesium-deficient areas. However, dolomitic limestone is recommended for crops that are grown to best advantage on a

TABLE III

EXCHANGEABLE CATIONS AND THEIR RATIOS IN SOILS AND IN CHLOROTIC AND NORMAL LEAVES, CUMBERLAND PLATEAU

Crop	Magnesium Deficiency	Milliequivalents of Cations				Cation Ratios		
		Mg	Ca	K	Total	Ca:Mg	K:Mg	Ca+K:Mg
				Soils				
Broccoli	None	0.12	2.3	0.12	2.54	19.1	1.00	20.10
"	Severe	0.12	5.0	0.17	5.29	41.6	1.42	43.02
Sweet Corn	None	0.19	2.1	0.15	2.44	11.0	0.79	11.79
"	Severe	0.14	2.1	0.15	2.39	15.0	1.07	16.07
Dent Corn	None	0.16	3.2	0.17	3.53	20.0	1.06	21.06
"	Moderate	0.12	5.0	0.19	5.36	41.6	1.58	43.18
Snap Beans	None	0.16	4.0	0.14	4.30	25.0	0.88	25.88
"	Moderate	0.12	4.7	0.13	4.95	39.1	1.08	40.18
				Leaves				
Broccoli	None	24	55	81	160	2.3	3.4	5.7
"	Severe	14	67	88	169	4.8	6.3	11.1
Sweet Corn	None	16	27	56	99	1.7	3.5	5.2
"	Severe	7	31	71	109	4.4	10.1	14.5
Dent Corn	None	18	25	57	100	1.4	3.2	4.6
"	Moderate	12	32	58	102	2.7	4.8	7.5
Snap Beans	None	30	60	50	140	2.0	1.7	3.7
"	Moderate	19	72	55	146	3.8	2.9	6.7

TABLE IV

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM PLOTS RECEIVING VARIOUS LIMING TREATMENTS ON THE CUMBERLAND PLATEAU EXPERIMENT STATION

Treatment	pH	Milliequivalents of Cations			Cation Ratios	
		Ca	Mg	K	Ca:Mg	K:Mg
None	5.1	0.78	0.26	0.29	3.0	1.12
1 Ton Calcitic Limestone	5.3	1.70	0.25	0.28	6.8	1.12
2 Tons Calcitic Limestone	5.8	3.30	0.18	0.24	18.3	1.33
1 Ton Calcium Silicate Slag	5.3	1.90	0.31	0.23	6.1	0.74
2 Tons Calcium Silicate Slag	5.5	3.20	0.25	0.24	12.8	0.96
2.5 Tons Calcium Silicate "	5.8	3.70	0.22	0.28	16.8	1.27
1 Ton Dolomitic Limestone	5.4	1.50	1.01	0.26	1.4	0.26
2 Tons Dolomitic Limestone	5.8	1.90	1.13	0.24	1.6	0.21
2.5 Tons Dolomitic Limestone	5.9	1.80	1.29	0.23	1.4	0.18

well-limed soil. Since most of the crops produced on the Cumberland Plateau, except for some vegetable crops, are in the latter category, dolomitic limestone should be preferable to the low-magnesium liming materials normally used in the area. Magnesium deficiency symptoms have been observed in corn on plots at the Cumberland Plateau Experiment Station receiving calcitic limestone. Adjoining plots of corn, treated with dolomitic limestone, did not show these deficiency symptoms. Soil samples were taken from the series of plots receiving various kinds and amounts of liming materials to determine their pH and exchangeable cations. The samples were collected and analyzed about two years after the plots were limed. The analyses are presented in Table IV. These data reveal that dolomitic limestone was an excellent source of available magnesium as well as calcium. The calcitic limestone and the calcium silicate slag, especially at the highest rates, increased the exchangeable calcium to such a high level that the Ca:Mg ratios were much wider than those of the unlimed soils.

Highland Rim

The soils of this region were developed from cherty limestone, with some shale and sandstone parent material at the higher elevations. They are generally considered to be higher in fertility than the soils of the Cumberland Plateau. Relatively few cases of magnesium deficiency symptoms have been reported in this area. Beasley (6) observed eight fields of corn on the Highland Rim exhibiting magnesium deficiency symptoms. The soils contained from 0.29 to 0.78 me. of magnesium, while the Ca:Mg ratios were from 7.5:1 to 20.6:1.

The pH, exchangeable cations, and cation ratios of 91 soil samples collected from counties in this area are given in Table V. The exchangeable magnesium varied from 0.08 to 1.60 me., averaging 0.54 me. This average amount of magnesium is over twice that of the Plateau samples. The percentage of the soils testing very low, low, medium, and high were 6.6, 25.3, 53.8, and 14.3 respectively. The Ca:Mg ratios varied from 2.0:1 to 62.5:1. The average ratio for all samples was 9.2:1. Forty-four, or 48 per cent, of the soils had ratios greater than 10:1; thirty of the soils had pH values greater than 6.0. The pH and the calcium levels of these soils indicate a liming program on the fields had been followed. The average amount of potassium in the soils of the Highland Rim was about the same as that in the Plateau soils; however, the mean K:Mg ratio was only 0.37 compared to 0.79 for the Plateau samples.

Central Basin

The soils of this region were derived for the most part from limestones, and are considered to be among the most fertile soils of the state. A few cases of deficiency symptoms similar to those caused by a magnesium deficiency have been reported from this area. Recent studies on crop response to zinc, magnesium, and other micro-elements, however, indicate that many deficiency symptoms in corn reported in this area may have been caused by inadequate zinc rather than magnesium.

Results of analyses of 83 soil samples from counties in the Central Basin are presented in Table VI. The exchangeable magnesium

TABLE V

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE HIGHLAND RIM

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
1	Cannon	5.7	5.0	0.08	0.10	62.5	1.25
2	"	5.9	7.5	0.72	0.24	10.4	0.33
3	"	6.2	6.5	0.47	0.18	13.8	0.38
4	"	5.7	6.0	0.49	0.14	12.2	0.29
5	Clay	5.6	6.2	1.27	0.18	4.8	0.14
6	"	5.9	3.6	0.41	0.46	8.7	1.12
7	Coffee	6.1	3.5	0.12	0.09	29.1	0.75
8	DeKalb	5.3	1.2	0.10	0.04	12.0	0.40
9	"	6.8	6.2	0.62	0.09	10.0	0.15
10	Dickson	7.0	8.2	0.43	0.22	19.0	0.51
11	"	5.4	2.6	0.88	0.23	2.9	0.26
12	"	6.2	2.8	0.35	0.17	8.0	0.49
13	"	6.0	6.2	0.72	0.38	8.6	0.53
14	Franklin	5.5	3.2	0.41	0.20	7.8	0.49
15	Giles	6.5	6.2	0.53	0.28	11.7	0.53
16	"	5.8	6.0	0.66	0.38	9.0	0.59
17	"	5.7	4.7	0.49	0.04	9.5	0.08
18	"	6.2	5.8	0.47	0.10	12.3	0.21
19	Hickman	5.8	4.7	0.41	0.18	11.4	0.44
20	"	5.9	5.8	0.53	0.10	10.9	0.19
21	Humphreys	6.1	2.8	0.43	0.13	6.5	0.30
22	Jackson	5.7	5.8	0.51	0.20	11.3	0.39
23	"	6.4	11.7	0.91	0.26	12.8	0.29
24	Lawrence	5.6	6.5	1.03	0.29	6.3	0.28
25	"	6.5	7.2	0.72	0.59	10.0	0.82
26	"	5.5	4.2	0.25	0.06	16.8	0.24
27	"	6.3	4.5	0.31	0.13	14.5	0.42
28	"	5.7	2.6	0.37	0.20	7.0	0.54
29	"	6.0	2.3	0.12	0.09	19.1	0.75
30	"	6.9	4.8	0.21	0.12	22.8	0.57
31	"	5.2	2.0	0.29	0.13	6.9	0.45
32	"	5.4	2.0	0.53	0.18	3.7	0.34
33	"	6.4	4.7	0.83	0.27	5.6	0.33
34	"	5.1	1.0	0.12	0.08	8.3	0.67
35	"	5.2	2.5	0.39	0.18	6.4	0.46
36	"	6.8	4.0	0.19	0.13	21.0	0.68
37	"	5.6	5.0	0.78	0.26	6.4	0.33
38	"	5.7	4.5	0.66	0.13	6.8	0.20
39	Macon	6.4	4.5	0.23	0.12	19.5	0.52
40	"	6.7	7.0	0.41	0.17	16.6	0.40

TABLE V (continued)

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE HIGHLAND RIM

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
41	Macon	6.3	3.8	0.29	0.27	13.1	0.93
42	"	5.3	2.5	0.37	0.04	6.7	0.11
43	Montgomery	8.2	7.0	0.53	0.04	13.2	0.08
44	"	6.5	4.7	0.58	0.20	8.1	0.34
45	"	7.3	6.2	0.66	0.42	9.3	0.64
46	"	6.7	4.7	0.56	0.23	8.3	0.41
47	"	6.1	4.7	0.41	0.17	11.4	0.41
48	"	6.4	6.0	1.19	0.19	5.0	0.16
49	"	6.7	5.0	0.62	0.56	8.0	0.90
50	"	5.9	3.7	0.45	0.20	8.2	0.44
51	"	6.1	3.8	0.25	0.06	15.2	0.24
52	"	5.1	2.7	0.68	0.13	3.9	0.19
53	"	5.9	3.5	1.03	0.15	3.4	0.15
54	Moore	6.8	6.8	0.53	0.13	12.8	0.25
55	Robertson	5.6	5.5	0.29	0.10	18.9	0.34
56	"	6.5	7.0	0.41	0.13	17.0	0.32
57	"	7.0	5.2	0.37	0.10	13.6	0.26
58	"	5.4	5.0	1.35	0.29	3.7	0.83
59	"	5.9	5.2	0.56	0.24	9.2	0.43
60	"	6.9	7.7	0.39	0.20	19.9	0.51
61	"	5.7	1.5	0.29	0.17	6.0	0.59
62	"	5.6	3.3	0.49	0.14	6.7	0.29
63	"	6.0	3.7	0.49	0.20	7.5	0.41
64	"	5.8	4.2	0.45	0.28	9.3	0.62
65	"	5.8	4.7	0.56	0.13	8.3	0.23
66	"	5.2	5.2	1.05	0.26	4.9	0.25
67	"	6.2	5.2	0.74	0.29	7.0	0.39
68	"	5.7	3.6	0.35	0.20	10.2	0.57
69	"	6.6	5.5	0.45	0.18	12.2	0.40
70	"	7.0	6.2	0.27	0.26	22.9	0.96
71	"	5.9	4.2	0.29	0.10	14.4	0.34
72	Stewart	6.4	4.7	0.82	0.24	5.7	0.29
73	Sumner	6.8	5.5	0.33	0.12	16.6	0.36
74	"	6.3	5.7	1.60	0.43	3.5	0.27
75	"	6.7	4.2	0.70	0.31	6.0	0.44
76	"	5.7	6.2	0.74	0.12	8.3	0.16
77	"	6.3	8.5	0.60	0.18	14.1	0.30
78	"	7.2	8.5	0.58	0.46	14.6	0.80
79	"	6.0	5.7	0.82	0.19	6.9	0.23
80	"	5.7	4.5	0.55	0.22	8.1	0.40

TABLE V (concluded)

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE HIGHLAND RIM

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
81	Sumner	6.1	3.1	0.55	0.27	5.5	0.49
82	"	7.8	4.0	0.37	0.22	10.8	0.59
83	"	5.7	4.0	0.60	0.23	6.6	0.38
84	"	6.2	6.1	0.47	0.09	12.9	0.19
85	"	6.9	7.5	0.49	0.09	15.3	0.18
86	"	6.9	7.0	0.33	0.06	21.3	0.18
87	"	7.0	7.0	0.31	0.05	22.5	0.16
88	Warren	5.4	1.5	0.74	0.28	2.0	0.38
89	Wayne	6.8	5.5	0.49	0.20	11.8	0.41
90	"	5.2	3.3	0.37	0.12	8.9	0.32
91	White	6.3	6.2	0.82	0.24	7.5	0.29

TABLE VI

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE CENTRAL BASIN

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
1	Bedford	5.7	10.5	0.56	0.13	18.7	0.23
2	Davidson	5.6	2.2	0.58	0.20	3.7	0.34
3	"	5.4	3.3	0.43	0.18	7.6	0.42
4	"	6.4	6.5	0.78	0.20	8.3	0.26
5	"	7.4	14.0	0.68	0.10	20.5	0.15
6	"	7.4	11.0	1.09	0.51	10.1	0.47
7	"	6.9	15.0	1.23	0.48	12.2	0.39
8	"	7.1	7.7	0.53	0.09	14.4	0.17
9	"	6.1	8.2	0.99	0.24	8.2	0.24
10	"	6.4	7.5	0.97	0.22	7.7	0.23
11	"	5.1	3.2	0.47	0.12	6.8	0.26
12	"	7.3	6.0	1.03	0.31	5.8	0.30
13	"	6.1	7.5	0.43	0.09	17.4	0.21
14	"	5.9	5.5	0.51	0.20	10.7	0.39
15	"	7.0	4.2	1.09	0.09	3.8	0.08
16	"	5.4	5.2	0.74	0.22	7.0	0.30
17	"	5.6	4.0	1.66	0.34	2.3	0.20
18	"	7.1	11.0	1.19	0.70	9.2	0.59
19	"	6.5	6.5	0.39	0.04	16.6	0.10
20	"	6.2	6.5	0.62	0.27	10.4	0.44
21	"	7.2	7.5	0.70	0.89	10.7	1.27
22	"	5.9	2.1	0.37	0.14	5.6	0.38
23	Lincoln	5.4	6.0	0.37	0.09	16.2	0.24
24	"	6.2	4.2	0.28	0.08	15.0	0.29
25	"	5.5	3.1	0.37	0.13	8.3	0.35
26	"	6.0	2.6	0.51	0.26	5.1	0.51
27	"	7.2	15.0	0.66	0.28	22.7	0.42
28	"	6.6	10.0	1.20	0.13	8.3	0.11
29	"	5.4	8.5	0.76	0.08	11.1	0.11
30	"	7.3	3.8	0.08	0.04	47.5	0.50
31	Maury	6.1	12.5	0.53	0.14	23.5	0.26
32	"	6.1	5.3	0.62	0.15	8.5	0.24
33	"	5.6	7.5	0.62	0.08	12.5	0.13
34	"	6.8	13.5	0.62	0.17	21.7	0.27
36	"	6.8	6.7	1.03	0.45	6.5	0.44
36	"	6.5	4.7	0.62	0.12	7.5	0.19
37	Marshall	6.4	6.2	0.53	0.23	11.7	0.43
38	"	5.2	5.2	0.47	0.20	11.0	0.43
39	"	5.8	6.0	0.43	0.28	13.9	0.65
40	Rutherford	5.9	11.5	0.72	0.29	15.9	0.40

TABLE VI (continued)

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE CENTRAL BASIN

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
41	Rutherford	6.3	8.2	0.82	0.15	10.0	0.18
42	"	6.7	8.0	0.45	0.22	17.7	0.49
43	"	5.6	4.7	0.53	0.24	8.8	0.45
44	"	7.1	7.5	0.58	0.46	12.9	0.79
45	"	7.4	11.7	0.56	0.29	20.8	0.52
46	"	5.3	4.7	0.53	0.20	8.8	0.38
47	"	6.0	5.8	0.53	0.18	10.9	0.34
48	Smith	6.0	7.0	0.41	0.12	17.0	0.29
49	"	6.6	5.0	1.21	0.51	4.1	0.42
50	"	7.4	5.7	1.05	0.51	5.4	0.49
51	"	5.6	3.6	0.51	0.10	7.0	0.20
52	"	5.9	6.2	0.45	0.06	13.7	0.13
53	"	6.7	6.7	0.53	0.35	12.6	0.66
54	"	5.4	3.0	0.80	0.18	3.7	0.23
55	"	7.0	7.7	0.72	0.08	10.6	0.11
56	"	6.4	7.5	0.99	0.42	7.5	0.42
57	"	5.9	3.6	0.56	0.24	4.0	0.27
58	"	5.8	5.2	0.37	0.10	9.2	0.18
59	"	7.0	5.2	0.37	0.10	14.0	0.27
60	"	6.5	5.7	0.68	0.58	8.3	0.85
61	"	5.6	5.8	0.49	0.31	11.8	0.63
62	"	6.1	4.7	0.31	0.20	15.1	0.65
63	Trousdale	7.0	11.0	0.49	0.22	22.3	0.45
64	"	5.4	3.3	0.33	0.10	10.0	0.30
65	Williamson	5.7	1.7	0.68	0.20	2.5	0.29
66	"	5.7	4.0	0.43	0.10	9.3	0.23
67	"	5.7	1.0	0.19	0.15	5.2	0.79
68	"	7.0	11.7	0.45	0.12	26.0	0.27
69	"	6.0	5.8	0.76	0.17	24.1	0.22
70	"	6.5	6.2	0.33	0.22	18.7	0.67
71	"	7.0	10.5	0.21	0.09	50.0	0.43
72	"	6.7	4.5	0.35	0.06	12.8	0.17
73	"	6.7	6.2	0.45	0.18	16.6	0.40
74	"	7.2	13.5	0.35	0.05	38.6	0.14
75	"	7.0	10.5	0.25	0.14	42.0	0.56
76	Wilson	5.8	6.7	0.58	0.09	11.5	0.16
77	"	5.8	7.5	0.91	0.18	8.2	0.20
78	"	6.2	6.2	0.62	0.09	9.1	0.13
79	"	6.2	7.5	0.58	0.26	12.9	0.45
80	"	6.2	8.2	0.70	0.29	11.7	0.41

TABLE VI (concluded)

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE CENTRAL BASIN

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
81	Wilson	6.2	7.7	0.60	0.20	12.8	0.33
82	"	5.0	5.2	0.93	0.32	5.5	0.34
83	"	5.6	8.5	0.56	0.06	15.1	0.11

varied from 0.08 to 1.66 me. The average amount for these soils was 0.63 me., which is more than two and one-half times greater than the average for the Cumberland Plateau and slightly higher than the average magnesium content of the Highland Rim soils. The percentage of the samples testing very low, low, medium, and high were 2.4, 16.9, 62.7, and 18.0 respectively. The Ca:Mg ratios ranged between 2.3:1 and 50:1 averaging 10.9:1 for the area. Forty-nine or 60 per cent of the samples had ratios greater than 10:1. Thirty-two of the latter soils had pH values greater than 6.0. Only thirteen of the 83 samples had K:Mg ratios greater than 1:2.

Beasley (6) found eight corn fields in this area showing what he considered to be magnesium deficiency symptoms. The magnesium in these soils varied from 0.5 to 0.95 me., and the Ca:Mg ratios varied from 9.2:1 to 18.1:1. Seven of the fields had received calcitic limestone; five of these had a pH greater than 7.0, while the other two had pH values of 6.1 and 6.9. Ten corn fields in this area without deficiency symptoms had from 0.62 to 1.52 me. of magnesium and Ca:Mg ratios of 4.8:1 to 10.4:1. The K:Mg ratios were relatively narrow in all the soils.

East Tennessee Valley

The soils of the East Tennessee Valley were derived from dolomite, dolomitic limestone, calcitic limestone, calcareous shale, and sandstone; the great majority is derived from the limestones. The agricultural lime used in this area is largely from high-magnesium limestone, therefore, limed soils regardless of their parent material would be expected

to be rather high in magnesium.

The pH, cation levels and cation ratios of 125 soil samples from this area are recorded in Table VII. The exchangeable magnesium ranged from 0.10 to 1.93 me. The average for the area was 0.83 me. Forty per cent of the samples tested high, 44.8 per cent medium, 12.8 per cent low, and only 2.4 per cent tested very low. The Ca:Mg ratios of the samples varied between 2.0:1 and 22.4:1, with a mean of 5.8:1. Only 15 per cent of the 125 samples had Ca:Mg ratios greater than 10:1. Thirteen of these 19 samples had pH values greater than 6.0. The average amount of potassium in the soils of this region was somewhat higher than the other areas; however, only 30 of the soils had K:Mg ratios greater than 1:2.

West Tennessee

This region of the state includes soils derived from loess, marine deposits of sand and clay, and alluvium deposited by the Tennessee and Mississippi Rivers. The soils are younger than most of the soils in other regions of the state. Relatively few known cases of magnesium deficiency symptoms have been reported from this region.

One hundred and thirty samples from this area were analyzed. The results are shown in Table VIII. The magnesium ranged between 0.12 and 2.63 me., with an average of 1.12 me. Over one-half of the samples contained more than 1.0 me. of exchangeable magnesium. The percentage of the samples testing very low, low, medium and high were 0.8, 5.4, 23.8 and 70.0 respectively. These data reveal that most of the soils

of this region are much higher in magnesium than the other regions of the state. The Ca:Mg ratios of the soils were from 0.3:1 to 20.5:1 with an average of 3.8:1. Only 12 of the samples had ratios greater than 10:1; seven of these had pH values greater than 6.0. The magnesium was high enough in 123 of the 130 soils to give K:Mg ratios less than 1:2.

Magnesium deficiency symptoms were seen in corn fields in Hardin County in 1950. Soil samples from five fields with magnesium deficiency symptoms and from one field of normal corn were analyzed. The results are presented in Table IX. It will be noted that the exchangeable magnesium in the soil on which normal corn was growing is much greater than in the soils producing deficient plants. Differences in the pH values and the Ca:Mg ratios are of some interest. Fields five and six had received six tons of calcium silicate slag in 1945, while the adjoining field, one, received only 4.5 tons of slag. Fields two and three received moderate applications of coarsely-ground limestone, while field two was not limed. The exchangeable magnesium in these soils is less than that found in the average West Tennessee soil. They are terrace soils in the Tennessee River alluvian areas, whereas, most of the samples reported in Table VIII were from the loess area.

The data presented in Tables II, V, VI, VII and VIII have been summarized. The range and mean values for the exchangeable cations in the soils of each region are given in Table X. The per cent of the soils in each region testing very low, low, medium, and higher is presented in Table XI. The range and mean Ca:Mg and K:Mg ratios of the five regions are given in Table XII.

TABLE VII

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE EAST TENNESSEE VALLEY

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
1	Bledsoe	6.3	4.7	0.62	0.35	7.6	0.56
2	Blount	5.5	4.7	0.95	0.20	4.9	0.21
3	"	5.8	4.7	0.51	0.08	9.2	0.16
4	"	7.5	4.2	1.09	0.15	3.8	0.14
5	Bradley	5.5	7.5	0.99	0.28	7.5	0.28
6	"	6.1	7.5	0.56	0.12	13.3	0.21
7	"	5.3	2.2	0.43	0.15	5.1	0.35
8	"	6.6	4.0	1.44	0.18	2.7	0.13
9	"	5.4	5.2	0.64	0.17	8.1	0.27
10	"	5.5	2.7	0.41	0.29	6.5	0.71
11	Carter	6.0	3.5	1.35	0.11	2.5	0.08
12	"	6.4	5.5	1.85	0.18	2.9	0.10
13	"	6.3	4.5	0.49	0.11	9.1	0.22
14	"	7.2	4.5	1.15	0.12	3.9	0.10
15	"	5.8	3.7	1.01	0.19	3.6	0.10
16	"	5.5	2.7	0.56	0.38	4.8	0.68
17	"	6.2	3.1	0.76	0.36	4.0	0.47
18	"	6.1	5.2	0.66	0.24	7.8	0.36
19	Carter	7.4	6.7	1.89	0.38	3.5	0.20
20	"	7.1	5.7	1.68	0.33	3.3	0.20
21	"	5.6	2.1	0.49	0.18	4.2	0.37
22	"	6.8	7.2	1.68	0.20	4.2	0.12
23	"	6.3	4.2	0.64	0.28	6.5	0.44
24	"	5.9	3.1	0.43	0.28	7.2	0.65
25	"	6.1	6.0	0.97	0.28	6.1	0.29
26	"	6.8	6.5	1.68	0.27	3.8	0.16
27	Cocke	6.1	4.5	0.58	0.08	7.7	0.14
28	"	7.0	4.5	0.99	0.44	4.5	0.44
29	Grainger	5.8	4.0	0.35	0.17	11.4	0.49
30	"	5.7	7.0	0.78	0.28	8.9	0.36
31	"	5.9	3.2	0.47	0.27	6.8	0.57
32	Greene	5.2	2.2	0.33	0.10	6.6	0.30
33	"	5.5	8.0	0.91	0.20	8.7	0.22
34	"	6.5	4.0	1.35	0.23	2.9	0.17
35	"	5.3	2.5	0.19	0.06	13.1	0.32
36	"	5.3	1.5	0.33	0.23	4.5	0.70
37	"	6.3	2.5	0.66	0.11	3.7	0.17
38	"	5.8	1.7	0.33	0.18	5.1	0.55
39	"	6.5	3.7	0.49	0.13	7.5	0.06
40	"	5.8	5.2	0.66	0.12	7.2	0.17

TABLE VII (continued)

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE EAST TENNESSEE VALLEY

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
41	Greene	5.0	4.7	0.68	0.14	6.9	0.21
42	"	8.0	11.7	0.29	0.26	40.3	0.90
43	Hamblen	6.3	6.7	0.78	0.24	8.5	0.31
44	"	5.8	2.5	0.31	0.10	8.0	0.32
45	"	6.7	4.7	0.78	0.17	6.0	0.22
46	"	5.6	4.0	0.47	0.27	8.5	0.57
47	"	6.4	3.7	0.62	0.08	5.9	0.13
48	Hancock	6.0	7.0	1.07	0.63	6.5	0.59
49	"	6.3	5.0	0.58	0.33	8.6	0.57
50	"	5.9	5.2	0.45	0.26	11.5	0.58
51	Hawkins	6.6	6.2	1.60	0.18	3.8	0.11
52	"	5.4	4.7	0.51	0.20	9.1	0.39
53	"	7.3	8.2	0.45	0.32	18.2	0.71
54	"	6.4	5.2	0.58	0.28	8.9	0.48
55	Jefferson	6.0	6.7	0.74	0.20	9.0	0.27
56	"	6.8	6.7	1.93	0.28	3.4	0.15
57	"	5.8	3.6	0.78	0.23	4.6	0.29
58	Knox	5.4	2.2	0.88	0.20	2.5	0.23
59	"	5.4	7.2	0.92	0.14	7.8	0.15
60	"	5.8	6.5	0.56	0.22	11.7	0.39
61	"	7.9	6.2	1.72	0.27	3.6	0.16
62	"	5.4	3.6	0.53	0.23	6.5	0.43
63	"	5.8	2.7	0.99	0.14	2.7	0.14
64	"	5.2	2.5	0.62	0.27	4.0	0.44
65	"	6.5	4.7	0.21	0.09	22.3	0.43
66	"	7.2	2.8	1.03	0.18	2.7	0.17
67	Johnson	7.4	6.2	1.81	0.11	3.4	0.06
68	"	5.5	1.2	0.33	0.20	3.6	0.61
69	"	6.2	4.5	1.03	0.22	4.3	0.21
70	Loudon	6.7	7.0	0.91	0.35	7.7	0.38
71	"	5.3	3.2	1.35	0.26	2.3	0.19
72	"	6.9	5.5	1.93	0.29	2.8	0.15
73	"	6.5	8.5	1.60	0.28	5.3	0.18
74	McMinn	6.1	4.0	1.45	0.26	2.7	0.18
75	"	7.2	5.0	1.09	0.20	4.5	0.18
76	"	6.8	6.1	0.31	0.13	19.6	0.42
77	"	6.7	3.6	0.97	0.22	3.7	0.23
78	Meigs	6.0	3.6	0.31	0.15	11.6	0.48
79	Monroe	6.5	5.5	1.03	0.23	5.3	0.22
80	"	6.7	6.2	1.35	0.26	4.5	0.19

TABLE VII (continued)

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE EAST TENNESSEE VALLEY

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
81	Monroe	5.4	3.5	0.33	0.51	10.6	1.55
82	"	6.8	6.5	1.81	0.44	3.5	0.24
83	"	8.0	7.7	0.74	0.36	10.4	0.49
84	"	5.6	2.2	0.27	0.14	8.1	0.52
85	"	5.8	4.1	0.82	0.47	5.0	0.57
86	"	7.2	4.0	1.05	0.20	3.8	0.19
87	"	6.2	5.0	0.60	0.53	8.3	0.88
88	"	5.8	3.3	0.45	0.26	7.3	0.58
89	"	5.7	3.6	0.76	0.31	4.7	0.41
90	"	6.3	5.0	1.03	0.51	4.8	0.50
91	Rhea	6.4	3.7	0.62	0.23	5.9	0.37
92	"	6.7	9.5	1.35	0.28	7.0	0.21
93	Roane	5.1	3.0	1.23	0.23	2.4	0.19
94	"	5.2	5.8	0.66	0.15	8.7	0.23
95	Sevier	5.5	5.5	0.56	0.13	9.8	0.23
96	"	6.8	3.5	1.68	0.27	2.0	0.16
97	Sullivan	7.1	6.5	0.29	0.20	22.4	0.70
98	"	7.0	6.2	0.66	0.22	9.3	0.33
99	"	5.5	4.0	0.31	0.20	12.9	0.65
100	"	6.3	2.8	0.74	0.15	3.7	0.20
101	"	6.5	12.5	1.23	0.20	10.1	0.16
102	"	5.6	3.5	0.53	0.29	6.6	0.55
103	"	5.9	8.5	1.48	0.26	6.6	0.18
104	"	5.7	2.2	0.53	0.09	4.1	0.17
105	"	6.5	3.5	1.19	0.15	2.9	0.13
106	"	5.6	3.5	0.76	0.34	4.6	0.45
107	"	5.4	1.6	0.16	0.18	10.0	1.13
108	"	6.4	4.1	0.41	0.50	10.0	1.22
109	"	5.7	3.1	0.62	0.28	5.0	0.45
110	"	5.3	1.8	0.23	0.19	7.8	0.83
111	"	6.1	3.3	0.66	0.20	5.0	0.30
112	"	6.5	4.0	0.91	0.24	4.4	0.26
113	"	5.5	2.8	0.33	0.17	8.4	0.52
114	"	7.1	5.5	1.48	0.13	3.7	0.09
115	Union	6.9	6.0	1.64	0.10	3.6	0.06
116	Washington	6.3	2.6	0.72	0.37	3.6	0.51
117	"	6.6	5.0	0.45	0.09	11.1	0.20
118	"	7.2	10.7	0.58	0.23	18.4	0.40
119	"	5.3	5.2	0.99	0.15	5.3	0.15
120	"	6.3	4.7	0.58	0.72	8.1	1.24

TABLE VII (concluded)

EXCHANGEABLE CATIONS, CATION RATIOS AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM THE EAST TENNESSEE VALLEY

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
121	Washington	7.9	10.5	0.10	0.06	10.2	0.60
122	"	7.0	5.0	0.43	0.55	11.6	1.30
123	"	6.1	4.1	0.60	0.38	6.8	0.63
124	"	6.1	3.6	0.86	0.23	4.1	0.27
125	"	5.3	5.2	0.99	0.15	5.2	0.15

TABLE VIII

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM WEST TENNESSEE

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:mg
1	Benton	5.5	2.5	0.74	0.14	3.4	0.19
2	Carroll	5.3	2.1	0.76	0.20	2.8	0.26
3	"	5.2	1.5	1.81	0.24	0.8	0.46
4	"	5.4	1.1	0.66	0.14	1.6	0.21
5	"	6.5	6.7	1.60	0.28	4.1	0.18
6	"	5.3	1.6	0.72	0.17	2.2	0.24
7	"	5.4	4.0	1.15	0.28	3.4	0.24
8	Crockett	6.0	4.5	0.91	0.26	4.9	0.29
9	"	5.2	4.2	1.92	0.28	2.1	0.15
10	"	5.1	2.5	1.07	0.09	2.3	0.08
11	"	5.0	2.1	2.06	0.15	1.0	0.07
12	"	5.7	4.7	1.23	0.09	3.8	0.07
13	"	5.6	2.2	1.11	0.12	1.9	0.11
14	"	5.5	2.8	1.11	0.12	2.5	0.11
15	"	5.6	3.5	1.11	0.15	3.1	0.14
16	"	5.2	2.3	1.07	0.17	2.1	0.16
17	"	5.9	4.8	1.07	0.10	4.4	0.09
18	"	5.3	1.7	1.19	0.14	1.4	0.12
19	"	5.6	2.5	0.91	0.08	2.7	0.09
20	"	5.9	4.2	0.76	0.12	5.5	0.16
21	"	5.8	3.0	0.95	0.17	3.1	0.18
22	"	7.3	6.2	0.66	0.08	9.3	0.12
23	"	6.2	2.8	0.84	0.04	3.3	0.05
24	"	5.3	4.0	1.03	0.15	3.8	0.15
25	"	5.7	4.7	0.98	0.27	4.7	0.28
26	Dyer	5.8	6.2	0.74	0.19	8.3	0.26
27	"	6.8	5.0	1.68	0.23	2.9	0.14
28	"	5.2	3.7	1.81	0.08	2.0	0.04
29	"	4.9	4.5	2.06	0.18	2.1	0.09
30	"	5.0	3.5	2.38	0.08	1.4	0.03
31	"	5.8	3.7	0.70	0.15	5.2	0.21
32	"	5.4	3.2	0.93	0.06	3.4	0.06
33	"	5.9	4.0	1.07	0.14	3.7	0.13
34	"	5.8	3.1	0.60	0.06	5.2	0.10
35	"	5.6	3.1	1.09	0.19	2.8	0.17
36	"	5.3	4.0	0.91	0.22	4.4	0.24
37	Fayette	5.2	2.0	1.93	0.18	1.0	0.09
38	"	5.2	4.2	1.72	0.18	2.4	0.10
39	"	5.0	2.0	1.81	0.20	1.1	0.11
40	"	7.4	8.5	1.35	0.32	6.3	0.24

TABLE VIII (continued)

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM WEST TENNESSEE

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
41	Fayette	7.5	7.7	1.03	0.20	7.4	0.19
42	"	5.7	3.1	0.76	0.15	4.0	0.20
43	"	7.7	8.2	0.62	0.29	13.2	0.47
44	"	5.4	2.0	0.91	0.10	2.2	0.11
45	Gibson	5.4	3.2	1.85	0.04	1.7	0.02
46	"	7.7	2.2	1.19	0.14	1.8	0.12
47	"	6.5	4.7	1.09	0.28	4.3	0.26
48	"	7.3	7.0	0.88	0.20	7.9	0.23
49	"	5.3	4.0	1.97	0.26	2.0	0.13
50	"	7.2	2.2	0.88	0.08	2.5	0.09
51	"	6.6	6.2	1.52	0.09	4.0	0.06
52	"	5.8	3.0	1.07	0.27	2.8	0.25
53	"	5.7	1.7	1.19	0.15	1.4	0.13
54	"	4.9	3.1	1.19	0.20	2.6	0.17
55	"	7.7	7.2	0.62	0.29	11.6	0.46
56	Hardeman	5.5	5.7	2.09	0.23	2.7	0.11
57	"	5.1	0.7	1.89	0.22	0.3	0.12
58	"	7.0	6.7	1.68	0.13	3.9	0.08
59	"	6.5	5.2	1.35	0.35	3.8	0.26
60	"	5.6	1.3	0.31	0.13	4.1	0.41
61	"	5.4	1.5	0.86	0.05	1.7	0.06
62	Hardin	5.1	2.6	1.19	0.18	2.1	0.15
63	"	4.9	1.5	1.19	0.17	1.2	0.14
64	"	5.6	2.1	0.64	0.14	3.2	0.22
65	"	5.4	1.7	0.37	0.08	4.5	0.22
66	"	4.8	1.7	1.52	0.17	1.1	0.11
67	"	5.3	1.7	1.31	0.22	1.3	0.17
68	"	4.9	0.7	0.27	0.08	2.7	0.30
69	"	6.0	7.7	1.05	0.19	7.3	0.09
70	"	6.9	8.0	0.39	0.22	20.5	0.56
71	"	5.3	2.8	0.25	0.08	11.2	0.32
72	"	6.2	3.3	0.51	0.14	6.4	0.27
73	"	5.5	1.0	0.12	0.12	8.3	1.00
74	Haywood	6.0	10.5	1.92	0.28	5.3	0.14
75	"	7.1	7.5	0.51	0.13	14.7	0.25
76	"	5.9	5.7	1.52	0.13	3.7	0.09
77	"	5.2	2.5	1.01	0.12	2.4	0.12
78	"	5.4	1.3	0.53	0.29	2.4	0.55
79	"	5.7	4.7	1.13	0.26	4.1	0.23
80	Henderson	6.1	12.5	0.53	0.12	23.5	0.23

TABLE VIII (continued)

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM WEST TENNESSEE

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
81	Henderson	5.8	6.8	0.45	0.08	15.1	0.18
82	"	5.1	2.2	0.86	0.20	2.5	0.23
83	"	5.3	1.8	0.33	0.23	5.4	0.70
84	"	5.3	2.7	0.97	0.27	2.7	0.28
85	"	5.4	2.3	0.56	0.09	4.1	0.16
86	Henry	5.3	2.2	0.91	0.10	2.4	0.11
87	Lauderdale	6.4	5.7	1.72	0.15	3.3	0.09
88	"	5.7	3.0	1.52	0.15	1.9	0.10
89	"	7.3	15.0	2.63	0.48	5.7	0.18
90	"	6.7	6.2	1.60	0.20	3.8	0.13
91	"	5.4	3.2	1.39	0.23	2.3	0.17
92	"	5.8	3.7	0.70	0.15	5.2	0.21
93	"	7.9	5.0	2.06	0.15	2.4	0.07
94	"	5.2	5.5	1.07	0.24	5.1	0.22
95	"	5.6	2.8	1.11	0.14	2.5	0.13
96	"	5.3	2.5	0.64	0.10	3.9	0.16
97	McNairy	5.5	9.5	0.93	0.29	10.2	0.31
98	"	5.2	5.8	0.53	0.18	10.9	0.34
99	Madison	6.4	7.0	0.78	0.76	9.0	0.97
100	"	7.0	7.5	1.11	0.27	6.7	0.24
101	"	6.1	3.2	0.58	0.26	5.5	0.45
102	Obion	5.6	7.5	0.66	0.23	11.3	0.35
103	"	6.2	5.2	1.68	0.06	3.1	0.04
104	"	5.1	2.7	1.93	0.12	1.4	0.06
105	"	5.2	5.2	1.89	0.18	2.7	0.10
106	"	5.2	5.5	2.63	0.27	2.0	0.10
107	"	6.3	7.7	1.93	0.10	3.9	0.05
108	"	6.8	10.7	2.38	0.20	4.5	0.08
109	"	6.3	3.8	0.78	0.18	4.8	0.23
110	"	6.9	5.7	0.41	0.20	13.9	0.49
111	"	6.5	4.2	0.95	0.20	4.4	0.21
112	Shelby	6.1	7.5	0.62	0.20	12.0	0.32
113	"	5.8	6.0	1.39	0.29	4.3	0.21
114	"	5.3	4.5	1.89	0.20	2.3	0.11
115	"	5.1	2.5	2.38	0.29	1.0	0.12
116	"	5.1	5.0	2.18	0.19	2.2	0.09
117	"	5.5	2.3	0.70	0.13	3.2	0.19
118	"	5.5	4.0	1.13	0.15	3.5	0.13
119	"	5.2	3.3	0.33	0.26	10.0	0.79
120	"	5.4	3.6	0.97	0.17	3.7	0.18

TABLE VIII (concluded)

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES COLLECTED FROM WEST TENNESSEE

Sample No.	County	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
121	Shelby	5.6	5.0	1.48	0.14	3.3	0.09
122	Tipton	7.7	6.0	0.72	0.14	8.3	0.19
123	"	5.2	2.2	1.64	0.20	1.3	0.12
124	"	6.3	6.0	1.93	0.15	3.1	0.08
125	"	5.3	2.2	1.23	0.18	1.7	0.15
126	"	6.1	3.5	1.09	0.20	3.2	0.18
127	Weakley	5.0	1.7	1.81	0.14	0.9	0.08
128	"	5.3	3.6	0.70	0.13	5.1	0.16
129	"	6.1	4.7	1.07	0.76	4.3	0.71
130	"	5.6	4.1	0.84	0.09	4.8	0.11

TABLE IX

EXCHANGEABLE CATIONS, CATION RATIOS, AND pH OF SURFACE SOIL SAMPLES FROM CORN FIELDS IN HARDIN CO., WEST TENNESSEE

Field No.	Magnesium Deficiency	pH	Milliequivalents of Cations			Cation Ratios	
			Ca	Mg	K	Ca:Mg	K:Mg
1	None	6.9	5.3	0.76	0.22	6.9	0.29
2	Moderate	6.7	4.2	0.41	0.10	10.2	0.24
3	Moderate	6.0	4.7	0.39	0.11	12.2	0.28
4	Moderate	5.2	3.8	0.40	0.08	9.5	0.16
5	Severe	8.2	7.5	0.31	0.17	24.1	0.55
6	Severe	7.8	7.5	0.35	0.19	21.1	0.54

TABLE X

SUMMARY BY REGIONS OF EXCHANGEABLE MAGNESIUM, CALCIUM AND POTASSIUM LEVELS IN SOIL SAMPLES OBTAINED FROM THE STATE SOIL TESTING LABORATORY

Region	No. of Samples	m.e. Magnesium		m.e. Calcium		m.e. Potassium	
		Range	Mean	Range	Mean	Range	Mean
Cumberland Plateau	62	0.05-0.53	0.24	0.25-7.5	3.70	0.07-0.38	0.19
Highland Rim	91	0.08-1.60	0.54	1.00-11.7	4.95	0.04-0.59	0.20
Central Basin	83	0.08-1.66	0.63	1.00-15.0	6.90	0.04-0.89	0.21
East Tennessee	125	0.10-1.93	0.83	1.20-12.5	4.80	0.06-0.72	0.24
West Tennessee	130	0.12-2.63	1.12	0.75-15.0	4.30	0.04-0.76	0.19

TABLE XI

PER CENT DISTRIBUTION OF EXCHANGEABLE MAGNESIUM LEVELS IN SURFACE SOIL SAMPLES FROM DIFFERENT REGIONS IN TENNESSEE

Region	Percentage of samples tested: Very Low[a]	Low[a]	Medium[a]	High[a]
Cumberland Plateau	43.5	37.1	19.4	0.0
Highland Rim	6.6	25.3	53.8	14.3
Central Basin	2.4	16.9	62.7	18.0
East Tennessee	2.4	12.8	44.8	40.0
West Tennessee	0.8	5.4	23.8	70.0

[a]Very low 0.04 to 0.21 m.e. (10 to 50 lbs. per acre)
Low 0.21 to 0.41 m.e. (50 to 100 lbs. per acre)
Medium 0.41 to 0.82 m.e. (100 to 200 lbs. per acre)
High 0.82 m.e. and above (200 lbs. and above per acre)

TABLE XII

RANGE AND MEAN VALUES FOR EXCHANGEABLE CATION RATIOS FOR SOIL SAMPLES FROM DIFFERENT REGIONS OF TENNESSEE

Region	Ca:Mg Ratios		K:Mg Ratios		Ca+K:Mg Ratios	
	Range	Mean	Range	Mean	Range	Mean
Cumberland Plateau	3.1-86.6	15.4	0.20-2.25	0.79	3.51-88.60	16.19
Highland Rim	2.0-62.5	9.2	0.08-1.25	0.37	2.38-63.75	9.57
Central Basin	2.3-50.0	10.9	0.10-1.27	0.33	2.50-50.43	11.23
East Tennessee Valley	2.0-22.4	5.8	0.06-1.55	0.29	2.16-41.20	6.09
West Tennessee	0.3-20.5	3.8	0.02-1.00	0.17	0.42-23.72	3.97

CHAPTER V

DISCUSSION AND CONCLUSIONS

The amount of exchangeable magnesium in soils is one factor influencing the absorption of the elements by plants. Bear et al (5) suggest that magnesium deficiency symptoms are likely to occur when the percentage of the exchange complex occupied by magnesium is less than six. They further point out that approximately ten per cent of the exchange complex of the "ideal soil" should be occupied by magnesium. The uptake of magnesium by plants is perhaps more closely related to the available supplies of the element at lower fertility levels than at high fertility levels.

The relative amounts of other cations, especially calcium and potassium, present in the exchange complex also influence the plant uptake of magnesium. Calcium, magnesium and potassium perform certain specific functions in plants. Any factor which interferes with these functions means a reduction in quality and quantity of plant growth. In spite of these specific functions attributed to each cation, there are many physiological functions performed in common by any of the three elements. The interchangeability of the basic cations in performing these functions probably would have little effect on the yield and quality of crops. However, any extreme lack of balance between calcium, magnesium and potassium is not desirable because the specific functions of these elements is not interchangeable. High ratios of calcium and/or potassium to the magnesium in soils have been considered to be limiting

factors in magnesium absorption by plants (4,5,13,17,22,29,38). While definite ratios have not been worked out for all conditions, it has been found that many plants are unable to absorb sufficient magnesium when the soil Ca:Mg ratio is greater than 10:1 or the K:Mg ratio is greater than 1:2 (5). Magnesium absorption will no doubt be inadequate if the combined Ca:Mg and K:Mg ratios are high even if each ratio is not excessively wide.

Upon examination of the data presented it is immediately apparent that the amount of exchangeable magnesium in the soils of Tennessee is quite variable. The calcium and potassium levels also varied over a wide range. These variations in calcium and potassium were due, not only to differences in native fertility, but to differences in crop removal, liming and fertilization from soil to soil. The variation in magnesium is not affected as much by those practices since little magnesium has been added to most of the soils of the state and crops, in general, contain less magnesium than calcium or potassium. Although the amount of the exchangeable cations and their ratios in the soils vary within regions as well as between regions, certain conclusions can be made concerning the magnesium status of each region and differences between regions.

The analyses of soil samples from the Cumberland Plateau reveal that the virgin soils of the area are low in exchangeable magnesium (see Table I). The data in Tables II, III, X and XI indicate that most of the cultivated soils are also low in the element, in fact, many are much lower in magnesium than the suggested critical six per cent saturation even though the exchange capacities are low. Since approximately

81 per cent of the soils tested low or very low (see Table XI) compared to the 32 per cent for the Highland Rim soils, 19 per cent for the Central Basin soils, 15 per cent for the East Tennessee Valley soils and 6 per cent for the West Tennessee soils, the magnesium in most of the soils of the Plateau is much lower than the magnesium in the soils of the other regions of the state.

Many of the Plateau soils had Ca:Mg ratios greater than 10:1 (see Table II). The pH and calcium levels of many of these soils show that the wide ratios were caused by calcitic limestone additions as well as the low magnesium levels. The data in Table IV suggest that dolomitic limestone would be preferred to other liming materials to maintain favorable Ca:Mg ratios. The K:Mg ratios of most of the soils of the Plateau were wider than 1:2. The exchangeable potassium in the soils was not particularly high, the wide ratios being largely the result of low exchangeable magnesium.

Although Ca:Mg ratios greater than 10:1 and K:Mg ratios greater than 1:2 are considered to be unfavorable for magnesium absorption, the data in Table III indicate that some crops can tolerate the low magnesium and wide Ca:Mg or K:Mg ratios in the Plateau soils without showing magnesium deficiency symptoms. Extremely wide ratios, however, favored increases in calcium and potassium absorption, decreases in magnesium uptake and magnesium deficiency symptoms. The tendency toward cation constancy of each species supports the finding of Bear (5), Lucas et al. (25) and others. The wide K:Mg ratios in the leaves compared to those in the soils indicate the ease of potassium absorption compared to other cations. More liberal applications of potash fertilizers to the soils

of this area would probably result in higher potassium "luxury consumption" and decreased magnesium absorption.

The data on the Highland Rim soils (see Table V) and on the Central Basin soils (see Table VI) and the summaries in Tables X and XI indicate that some of the soils of these regions are low enough in exchangeable magnesium to expect some nutritional problems. However, it would seem that most of the soils have adequate supplies of magnesium unless the use of calcitic limestone and potash as a part of soil improvement programs widens the Ca:Mg ratios to the point where adequate magnesium absorption is prevented. Most of the magnesium deficient crops observed by Beasley (6) in these regions were growing on soils with wide cation ratios.

The cation ratio problem would probably be most critical on the shallow soils in these regions. Soils with parent rock or pans near the surface would limit root extension and prevent the roots from growing into the subsoils which would normally have more favorable Ca:Mg and K:Mg ratios.

The data in Tables VII, X, and XI reveal that most of the soils of the East Tennessee Valley contain sufficient magnesium for normal plant growth unless large amounts of calcium and potassium are applied. This is to be expected since many of the soils were developed from high-magnesium limestone and the liming material used is usually dolomitic limestone. A few soils are sufficiently low in magnesium or have wide Ca:Mg or K:Mg ratios to expect some magnesium problems. The soils developed from sandstone will probably be lower in magnesium than those

developed from limestones.

The results of the analyses of the West Tennessee soils (see Tables VIII, X and XI) reveal that most of the soils of this area are naturally high in exchangeable magnesium. A deficiency in plants would be expected only in cases of extreme lack of balance between magnesium and other cations. A comparative test of calcitic and dolomitic limestones, applied every five years to a rotation of cotton, corn, soybeans, wheat, clover and grass, was conducted over a period of seventeen years at the West Tennessee Experiment Station. Unpublished data[1] show no significant differences between the yields of the various crops treated with the two materials.

The data in Table IX indicate that the soils of the Tennessee River Alluvium area of West Tennessee may be lower in magnesium than most of the soils derived from loess parent material, and high calcitic liming materials may widen the Ca:Mg ratios in these soils to the point that magnesium deficiency symptoms may occur.

Additional studies are needed to evaluate the magnesium-supplying powers of Tennessee soils. Magnesium fertilization studies are needed, especially on the Cumberland Plateau soils, to determine the yield response of various crops and to evaluate the various commercial sources of magnesium.

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[1]Personal communication. O. H. Long, Associate Agronomist, The University of Tennessee, Experiment Station.

CHAPTER VI

SUMMARY

Magnesium deficiency in plants is usually due to either a low amount of exchangeable magnesium in the soil or an unbalanced condition existing between magnesium, calcium and potassium.

A chemical study was made of selected soil samples from five physiographical regions of Tennessee. The analyses included the determination of exchangeable magnesium, calcium and potassium; and soil reaction (pH). The Ca:Mg and K:Mg ratios of the soils were calculated. The cation content of normal and magnesium-deficient plant tissue samples from certain crops were also determined. Results of the analyses and some of the inferences drawn concerning the magnesium status of the soils of the state are briefly summarized below.

Most of the soils of the Cumberland Plateau contained less exchangeable magnesium and had wider Ca:Mg and K:Mg ratios than the amount of magnesium and ratios generally considered to be favorable for adequate magnesium absorption and optimum yields.

A high per cent of the soils of the East Tennessee Valley and West Tennessee tested medium to high in magnesium. The magnesium content of most of these soils is probably sufficient for normal plant growth unless the amounts of calcium and potassium are greatly increased by continued use of calcitic limestone and high-potassium fertilizers.

A majority of the Highland Rim and Central Basin soils was also medium or high in magnesium; however, a number of the soils contained less magnesium or had wider cation ratios than the suggested optimum.

Certain crops are apparently able to tolerate wide Ca:Mg and K:Mg ratios in soils without showing magnesium deficiency symptoms; however, it was found that extremely wide ratios favored increase in calcium and potassium absorption, decreased in magnesium absorption and magnesium deficiency symptoms.

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APPENDIX

APPENDIX

Extraction of Exchangeable Bases

Extracting Solution: Dissolve 82.09 grams of sodium acetate in water and dilute to 1 liter. Adjust the pH of the solution to 7 with acetic acid or sodium hydroxide.

Procedure: To 5 grams of soil (air dried and screened through a 20 mesh sieve) add 25 ml. of extracting solution and shake for 30 minutes in a mechanical shaker. Filter the suspension. Filtrates of soils low in organic matter will usually be clear. Approximately 0.25 grams of activated carbon should be added to soils high in organic matter before extraction. Soils with a high level of exchangeable bases should be leached with 50 ml. of extracting solution.

Determination of Magnesium

Reagents:

1. Standard Magnesium solution (25 p.p.m. Mg.): Dissolve 0.2205 grams of magnesium acetate tetrahydrate in 1 liter of the extracting solution.
2. Hydroxylamine hydrochloride solution (5%): Dissolve 25 grams of hydroxylamine hydrochloride in water and dilute to 500 ml.
3. Starch solution (2%): Make a paste of 2 grams of c.p. soluble starch with water and dissolve in 100 ml. of boiling water, stirring with a glass rod. A few drops of formaldehyde will preserve the solution for several days.

4. Compensating solution: Dissolve 4.4 grams of calcium acetate and 0.37 grams of aluminum sulfate in 500 ml. of water; mix to dissolve the salts. Dilute to 1 liter.

5. Starch reagent: Prepare this reagent daily as needed by mixing equal parts of starch solution and compensating solution.

6. Sodium hydroxide (3N): Dissolve 120 grams of sodium hydroxide in water and dilute to 1 liter. Store in a Pyrex glass bottle.

7. Titan yellow (0.2%): Dissolve 0.2 grams of titan yellow and 15 grams of sucrose in 100 ml. of water. Add a few drops of chloroform to preserve the solution. Store in a brown or amber glass bottle.

Procedure: Pipette 3 ml. of the filtered soil extract into a vial, add 0.5 ml. of hydroxylamine hydrochloride solution and 1 ml. of the starch reagent; mix, add 0.5 ml. of titan yellow solution and mix again; then add 1 ml. of sodium hydroxide solution and mix thoroughly. Allow to stand for 5 minutes and measure in a photolometer, using the green filter. Exchangeable magnesium in the soil is calculated by comparing photolometer readings of the soil extract solutions with standard magnesium solutions treated in the same way. The p.p.m. of magnesium in the soil extract multiplied by 10 (or by 20 when 50 ml. of extracting solution is used) equals pounds of magnesium per acre (2,000,000 pounds of soil).

Determination of Calcium

Reagents:

1. Standard calcium solution (200 p.p.m.): Dissolve 0.879 grams of calcium acetate monohydrate in 1 liter of the extracting solution. Preserve this solution by the addition of 1 ml. of chloroform per liter of solution.
2. Soap solution: Dissolve 0.6 grams of recrystalized stearic acid (Eastman reagent No. 402 or similar quality) and 7.5 ml. of oleic acid (U.S.P.) in 320 ml. of methanol by heating on a hot plate. Add 16 grams of ammonium carbonate dissolved in 80 ml. of hot water and boil for about 10 minutes. Cool, add 300 ml. of methanol, 40 ml. of water, and 1.6 ml. of concentrated ammonium hydroxide. Filter after 24 hours and store in a Pyrex glass-stoppered bottle.
3. Ammoniacal citrate: Dissolve 3.15 grams of citric acid in water, add 14 ml. of concentrated ammonium hydroxide, and dilute to 1 liter with water.

Procedure: Pipette 0.5 ml. of the soil extract into a photolometer vial, add 2 ml. of the ammonium citrate solution, mix, then add 1.5 ml. of the soap solution carefully down the side of the vial so as to form a layer on top of the solution. Mix rapidly and uniformly after the addition of the soap solution to all the vials. After 30 minutes measure in the photolometer, using the blue filter. Set the photolometer on 100 with the extracting solution. Calcium levels in the soil are calculated by comparing with readings for standard calcium solutions treated in the same way. The p.p.m.

can be converted to pounds per acre in the manner described under the magnesium procedure. (This test should not be attempted at temperature above 28° C. The temperature can be controlled by keeping one of the reagents in a refrigerator at 4 to 6° C.)

Determination of Potassium

Reagents:

1. Standard potassium solution (40 p.p.m.): Dissolve 0.0763 grams of potassium chloride in 1 liter of extracting solution. Preserve this solution by adding a few drops of chloroform.
2. Sodium cobaltinitrite solution: Dissolve 6.25 grams cobaltous nitrate and 75 grams of sodium nitrite in about 175 ml. water in a 250 ml. volumetric flask; add 5 ml. of 99.5 per cent glacial acetic acid, mix gently to prevent foaming, cover, and let stand overnight to permit the escape of nitrogen dioxide. Dilute to 250 ml. and mix well. Filter and store in a brown bottle in a refrigerator.
3. Methanol-isopropyl alcohol mixture (1:1).
4. Formaldehyde, C. P. 40 per cent.

Procedure: Pipette 2 ml. of the soil extract into a photolometer vial, add 6 drops of formaldehyde; let stand for 5 minutes. Add 1 ml. of sodium cobaltinitrite solution, mix well; then add 2 ml. of the alcohol down the side of the vial so as to form a layer on the top of the solution in the vial. After the last addition of

the alcohol to the extracts, mix the solutions rapidly and uniformly. Let stand for 5 minutes and then read in the photolometer with extracting solution set at 100 using the red filter. Potassium levels in the soil are determined by comparing the photolometer readings with those for standard potassium solutions treated in the same way. Pounds per acre can be calculated from p.p.m. by the method given in the magnesium procedure. Since temperature is important in this determination, keep one or more of the regents in a refrigerator at 4 to 6° C.