RESEARCH CIRCULAR 116 APRIL 1963

MAGNESIUM DEFICIENCY ON COLUMBIANA COUNTY SOILS

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OHIO AGRICULTURAL EXPERIMENT STATION

WOOSTER, OHIO

CONTENTS

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AGDEX 544

4-63-3M

MAGNESIUM DEFICIENCY ON COLUMBIANA COUNTY SOILS[1]

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INTRODUCTION

Various degrees of magnesium deficiency have been observed among several crops in Columbiana County during the past 10 years. In 1959, widespread magnesium deficiency symptoms appeared in sweet corn and potatoes and in some areas deficiency symptoms were observed in field corn, alfalfa and wheat. Several sweet corn growers also noted magnesium deficiency symptoms in ryegrass used as a cover crop following sweet corn. The severity and widespread occurrence of the deficiency in 1959 spurred action among many farmers to correct the deficiency that had been with them in varying degrees for several years.

REVIEW OF LITERATURE

Magnesium is an essential nutrient element for all plants. Its most important function is in chlorophyll formation and photosynthesis. Plants deficient in magnesium are chlorotic. Chlorosis develops first in the older leaves in the areas between the veins, starting along the edges of the leaves and developing toward the midrib. When the deficiency is severe, growth is stunted and the plants may die prematurely. In sweet corn, the under sides of the leaves on magnesium deficient plants were silvery and reflected light when the leaves were turned by the wind, resembling the flashing of light from a mirror.

Soils which are considered magnesium deficient have been defined in several ways. An "ideal soil" as defined by Bear, *etal* (2) contains about 10 percent magnesium on the exchange complex. They further predicted that soils with less than six percent magnesium on the exchange complex were deficient in magnesium. The majority of the soils in Columbiana County have exchange capacities of 9 to 13 meq. per 100 gms. of soil. Therefore, an "ideal soil" for Columbiana County should contain from 200 to 300 pounds of exchangeable magnesium per acre. A majority of the Columbiana County soils have less than 200 pounds of available magnesium per acre, and by the Bear, *etal* (2) defi-

[1]The authors wish to express their appreciation to County Agent Floyd Lower, and the farmers in Columbiana County for their cooperation during the period of investigation.

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nition are magnesium deficient. In Illinois, Key and Krutz (5) recommend a minium of 150 pounds of available magnesium with soils of low cation exchange capacities.

Magnesium availability is also influenced by the percent calcium and potassium on the cation exchange complex. Sanik, *etal* (11) found that maxium plant growth occurred when the molar ratio of calcium to magnesium was 4. McCollock, *etal* (6) found that where the ratio of potassium to magnesium exceeds 0.5, additional magnesium is needed to prevent magnesium deficiency from developing. Prince, *etal* (9) and others (2, 13, 15) consider the magnesium-potassium ratio a better estimate of magnesium availability than the level of exchangeable magnesium alone.

The antagonistic effect of potassium on the absorption of magnesium is well known (3, 10). Walsh and O'Donohoe (13), and Prince, *etal* (9) considered the level of potassium in the soil to be as equally important as the magnesium level due to this noted antagonism. Taylor and Smith (10) found sweet corn to be particularly sensitive to the magnesium-potassium soil ratio. The frequent occurrence of magnesium deficiency in sweet corn on the potato soils of Columbiana County has been in part the result of heavy fertilization with potash producing a high potassium to magnesium ratio. Also these soils have low calcium and magnesium clay saturation and, therefore, have a low soil pH.

Moore, *etal* (7) using excised barley roots found that the pH of the rooting medium had a marked effect upon the absorption of magnesium. Up to a pH of 4, no magnesium was absorbed by the roots. Absorption reached a maxium at pH 5.5 and the absorption rate remained constant to a pH of 9.0. Many of the magnesium deficient soils in Columbiana County have a pH less than 5.5 which may effect magnesium uptake.

SOILS AND MANAGEMENT PRACTICES

The majority of the soils in Columbiana are relatively low in available magnesium. The Wooster-Canfield and Ravenna-Trumbull soil series occupy the northern half of Columbiana County while Muskingum soil dominates the southern portion (8). Soils in the northern part (Wooster-Ravenna series) of the county are medium to high in available phosphorus and potassium, acid in reaction, and are low to medium in available magnesium (4). Soils in the southern part of the county (Muskingum series) are acid in reaction, low to medium in phosphorus and medium to high in potassium and magnesium (4). Magnesium deficiencies are not as common an occurrence on these Muskingum soils as in the Wooster-Ravenna soils.

The soils in Columbiana County are unique due to their high buffering capacity, and require unusually large quantities of lime in order to bring them to neutrality. The increasing frequency and severity of magnesium deficiency in the county has been due in part to inadequate liming and in part to the use of low magnesium bearing limestone.[3] Recently dolomitic limestone has been more readily available and more widely used.[4] Frequent liming and the wider acceptance of the dolomitic limestone should do much toward correcting the magnesium deficiency for many of the soils in the county.

Magnesium deficiency has been most severe on farms in which potatoes and sweet corn are in rotation. Sweet corn seems particularly sensitive to magnesium, particularly to the magnesium to potassium soil ratio (10). Large acreages of sweet corn were completely lost due to the deficiency in 1959. Potatoes are sensitive to a lack of adequate available magnesium; however, deficiencies in potatoes have not been as severe as those noted for sweet corn. Deficiencies in other crops have been only occasionally noted.

Climate seems to have a marked effect on the occurrence and severity of the deficiency. Although many farmers (which have had magnesium deficient crops) have in many instances not adequately limed their soils, the yearly variation in the occurrence and severity of the deficiency symptoms indicates that climate is exerting a significant influence. Widespread deficiencies noted in 1954 and 1959 appear to be associated with higher than normal June-July temperatures in these years.

Many of the farmers in Columbiana County obtain adequate control of magnesium deficiency in sweet corn and potatoes by spraying solutions of magnesium sulfate[5] on the leaves or applying magnesium sulfate[5] in the row at planting. Spray applications of 25 to 50 lbs. of magnesium sulfate per acre or 100 to 250 lbs. of magnesium sulfate per acre in the row provided good control. When applied in the row at the time of planting, the magnesium sulfate was normally placed alone, usually on the side opposite the normal row fertilizer. Spray or row application of magnesium sulfate meant an additional operation which added considerably to the cost of production. During the past few years, most potato and sweet corn growers have broadcast large quantities of magnesium sulfate. This method is effective but very costly.

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[3]Dolomite is a natural compound composed chiefly of carbonates of magnesium and calcium is substantially unimodal (1-1.19) proportions. A true dolomite contains 30.4 percent CaO and 21.8 percent MgO.

[4]Personal communication with Floyd Lower, county agent.

[5]The commonly used form is Epsom salt, $MgSO_4 \cdot 7H_2O$.

PRELIMINARY INVESTIGATIONS

In the summer of 1959, soil and plant samples were collected from a sweet corn field where the magnesium deficiency was severe. Soil and plant samples were taken in a deficient area and in an area where the deficiency was less severe. The results of tissue and soil analyses[6] are given in Table 1.

The only difference noted between these two areas was soil pH. Severe deficiency symptoms and low magnesium content of the plant were associated with the low pH and high potassium availability. The soil test level for magnesium is less than what has been recommended by others (2, 5) and the ratio of potassium to magnesium is conducive for the development of magnesium deficiency (6).

TABLE 1.–Analysis of Soil and Plant Tissue Taken from Field Exhibiting Magnesium Deficient Sweet Corn Plants, Columbiana County, 1959.

Degree of Magnesium Deficiency in Sweet Corn	Soil pH	Soil Available		Sweet Corn Leaf Tissue		
		K	Mg	K	Ca	Mg
		lbs./A	lbs./A	%	%	%
Severe, stunted plants	4.7	450	125	4.10	.74	.25
Moderate deficiency - plants normal height	5.2	450	125	3.76	.86	.65

In the spring of 1960, several areas were soil sampled where magnesium deficiency symptoms had been reported the previous year. The results of the soil analyses are given in Table 2. The low soil pH combined with the high potassium levels were associated with magnesium deficiency symptoms at many of the locations in 1959. Many of these fields were in a potato rotation where the management practices resulted in a low soil pH and high potassium availability.

In 1961 soil and plant samples were taken from a field of sweet corn where the deficiency was severe and an adjacent area where the plants were exhibiting minor deficiency symptoms. The results of the analysis of the soil and plant tissue are given in Table 3. Although the magnesium level of the soil was high, severe deficiency symptoms were again associated with the lower pH. Large quantities of chicken manure had

[6]All of the soil analyses included in Tables 1-3 were made at the Agricultural Extension Service Soil Testing Laboratory, Columbus, Ohio.

TABLE 2.–Analysis of Soils from Fields Where Magnesium Deficient Crops Appeared, Columbiana County, 1959.

Name of Farm	Soil Series	Crop and Noted Deficiency	Soil pH	Available K	Available Mg	Comments
				lbs./A	lbs./A	
McMaster*	Wooster-Ravenna	Mg deficiency in sweet corn 1959.	5.6	456	430	Applied lime and $MgSO_4$ in spring of 1960 to correct deficiency.
McMaster*	Wooster-Ravenna	No Mg deficiency in sweet corn 1959.	6.0	460	720	Same as above
Thompson	Muskingum	Wheat – no apparent Mg deficiency	6.3	720	50	)Low soil pH apparently)cause of Mg deficiency)in this field even
Thompson	Muskingum	Wheat – Mg deficiency very apparent.	4.8	460	72	)though the K levels are)high and Mg levels low.
Thompson	Muskingum	Mg deficiency in potatoes in 1959	5.3	720	145	Low soil pH and high K level resulting in Mg deficiency.
Wiler	Muskingum	Mg deficiency in field corn 1959.	6.2	160	48	Low Mg level.
Wiser	Wooster-Ravenna	Wheat-$MgSO_4$ applied, however, Mg deficiency, present.	7.2	480	24	Very low Mg level and high K level resulting in deficiency.
Wiser	Wooster-Ravenna	Wheat-$MgSO_4$ applied, no Mg deficiency.	6.8	340	100	K: Mg ratio is more favorable than location above.
Wiser	Wooster-Ravenna	Mg deficiency in potatoes in 1959.	6.4	412	100	K: Mg ratio not favorable.

*By liming and broadcasting sizeable quantities of $MgSO_4$, magnesium deficiency did not occur in 1960 or 1961 in these fields.

TABLE 3.–Analysis of Soil and Plant Tissue Taken from Field Exhibiting Magnesium Deficient Sweet Corn Plants, Columbiana County, 1961.

Degree of Magnesium Deficiency	Soil pH	Soil Available K	Soil Available Mg	Sweet Corn Leaf Tissue K	Sweet Corn Leaf Tissue Ca	Sweet Corn Leaf Tissue Mg
		lbs./A	lbs./A	%	%	%
Severe, plants stunted	4.1	500	300	3.32	.32	.14
Moderate deficiency-plants normal height	4.4	412	325	2.78	.65	.23

been applied to this area which significantly lowered the soil pH. This association between magnesium deficiency and low soil pH is a confirmation of Moore's *et al* (7) observations of the effect of pH upon magnesium absorption by plant roots.

RESULTS FROM GREENHOUSE STUDIES

I. Effect of Liming and Magnesium Fertilization on the Absorption of Magnesium by Field Corn, Sweet Corn, Ryegrass, and Potatoes.

An acid, low magnesium Muskingum soil from a potato farm in central Columbiana County was used in this study. Various quantities of dolomitic lime and magnesium (as magnesium sulfate) were added to establish several levels of soil pH and magnesium availability. The soils were cropped successively with field corn (Ohio Hybrid W64), sweet corn, ryegrass, and potato. The plants were harvested when approximately 6 to 10 inches tall. The tops were dried, weighed, ground and analyzed for magnesium content. The amount of magnesium removed by each crop was determined and related to soil pH and available soil magnesium level. The results are given in Tables 4 and 5 and illustrated in Figures 1 and 2.

Three treatment effects were studied as given in Table 4: (1) the influence of an increase in soil pH and available soil magnesium on magnesium uptake by treatments 1, 2 and 3; (2) the influence of increasing soil available magnesium with no change in soil pH treatments 2, 3, and 4, and (3) the influence of increasing soil magnesium with a moderate increase in soil pH by treatments 5, 6, and 9. With no increase in pH (treatments 2, 3, and 4) or with a moderate increase (treatments 5, 6, and 9) no marked increase in the uptake of magnesium with increasing soil available magnesium was noted for potatoes.

TABLE 4.–Magnesium Uptake by Corn, Sweet Corn, Ryegrass, and Potatoes from a Soil Limed and Fertilized with Magnesium.

Treatment Number	Soil Treatment	Soil pH	Soil Available Magnesium	Magnesium Uptake per Pot: Field Corn	Sweet Corn	Ryegrass	Potato
			lbs./A	mg	mg	mg	mg
1	Check	5.0	265	6.5	10.0	5.7	15.5
2	35 lb. Mg[2] acre	5.0	350	6.5	14.0	8.0	15.5
3	100 lb. Mg[2] acre	5.0	370	6.5	12.0	7.5	22.0
4	200 lb. Mg[2] acre	5.0	430	8.5	19.5	7.0	21.0
5	Dolomitic lime + 100 lb. Mg[2] acre	5.4	480	10.0	25.5	8.5	25.0
6	Dolomitic lime + 35 lb. Mg[2] acre	5.6	440	10.0	20.5	8.0	16.0
7	Dolomitic lime[1]	5.6	500	11.5	18.5	8.0	8.3
8	Dolomitic lime[1]	6.6	630	15.5	39.0	17.0	27.5
9	Dolomitic lime + 200 lb. Mg[2] acre	5.7	550	12.0	27.5	7.5	20.5
	L.S.D. (.05)			N.S.[3]	6.5	1.4	4.3
	L.S.D. (.01)			N.S.[3]	9.4	2.1	6.2

[1] Applied at a rate to obtain the soil pH as given.

[2] As $MgSO_4 \cdot 7H_2O$

[3] Not statistically significant.

With the use of dolomitic limestone, both a change in soil pH and available magnesium was accomplished. All four crops showed a marked increase in the uptake of magnesium as the amount of dolomitic applied increased.

Correlations between soil pH and yield and uptake of magnesium by the four crops were determined. The correlation coefficients are given in Table 5 and the regressions illustrated in Figures 1 and 2. Soil pH was found to be significantly related to the yield of ryegrass and potatoes, but not field or sweet corn. In the other comparison, soil pH was found to be significantly related to the uptake of magnesium by field and sweet corn, and ryegrass but not potatoes.

As the pH of the soil increased as a result of liming, the magnesium content of the soil also increased since dolomitic limestone was used. It is, therefore, difficult to separate the soil pH change effect upon yield

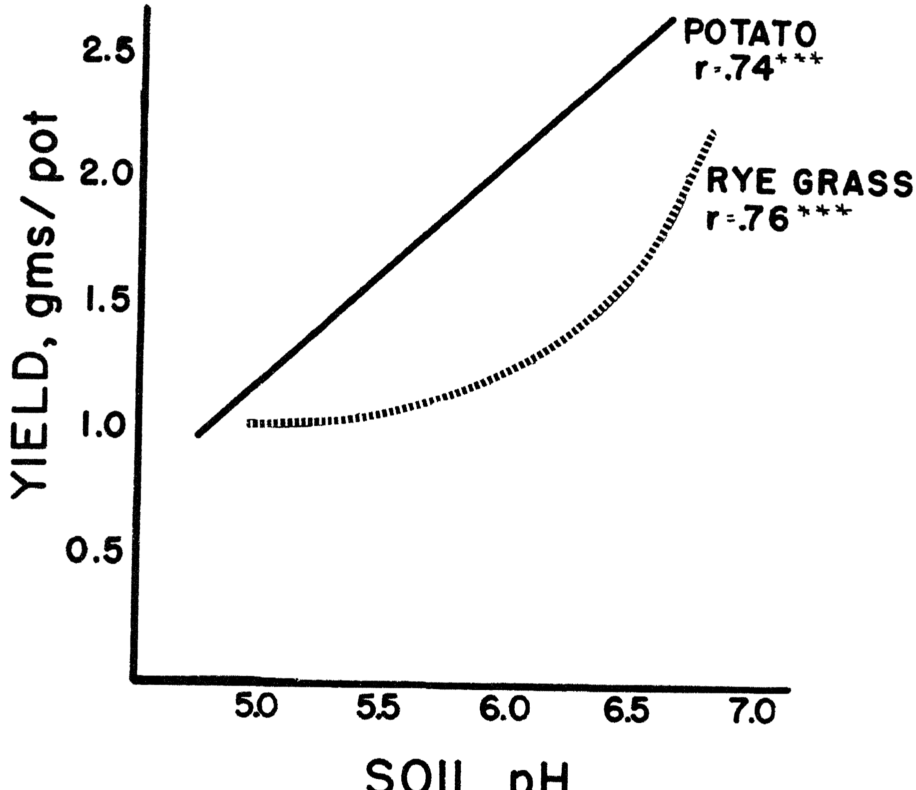

Fig. 1—Effect of soil pH on the yield of rye grass and potato.

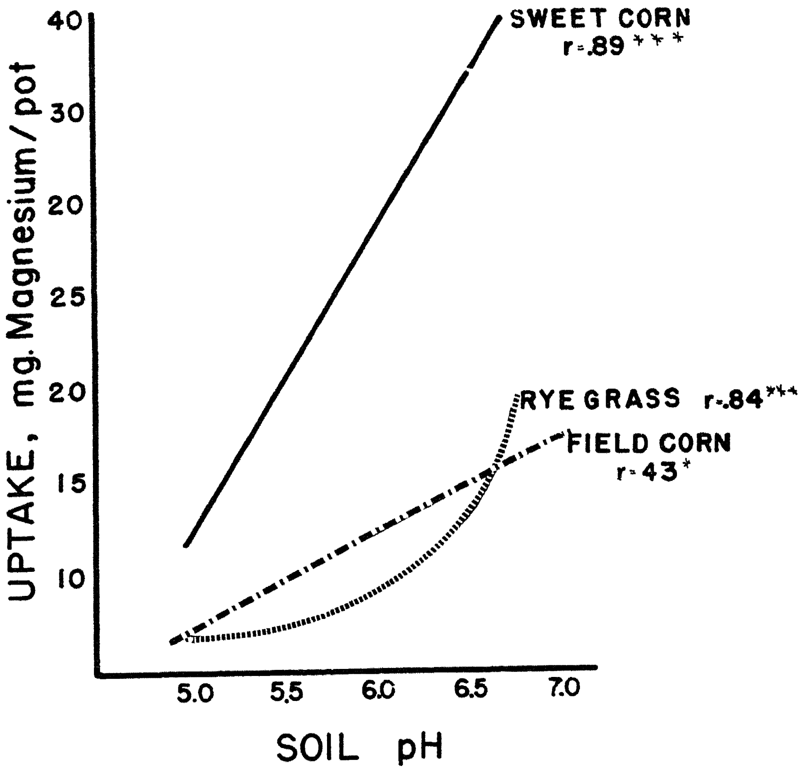

Fig. 2–Effect of soil pH on the uptake of magnesium by field corn, sweet corn and rye grass.

and magnesium uptake and the soil available magnesium change effect. However, the addition of magnesium to the soil without changing the soil pH can be made by comparing treatment 1 with 2, 3, and 4 (see Table 4). Soil magnesium additions increased the uptake of magnesium by sweet corn (at the 200 lb. rate only), ryegrass (all rates), and potato (100 and 200 lb. rates only). However, a change in soil pH seemed to have a far greater effect on magnesium uptake for all the crops except field corn than just magnesium addition alone.

In order to determine the effect of magnesium availability on magnesium uptake on an unlimed (pH 5.0) and limed (pH 6.5) soil, an acid low magnesium Muskingum soil was limed and magnesium added as magnesium sulfate. The treated soils were cropped with sweet corn, followed by ryegrass. The results of this experiment are illustrated in Figure 3.

TABLE 5.—Correlation of Soil pH with Yield and Uptake of Magnesium for Field Corn, Sweet Corn, Rye Grass and Potato.

Crop	Soil pH versus Yield "r"	Soil pH versus Magnesium Uptake "r"
Field Corn	.15 NS	.43*
Sweet Corn	.33 NS	.89**
Rye Grass	.76***	.84***
Potato	.74***	.25 NS

NS — Not significant.

*Significant at the 5% level.

***Significant at the 1% level.

As available soil magnesium increased, the uptake of magnesium also increased. Liming increased the uptake of magnesium over the unlimed soil for both crops. For sweet corn, the degree of change with increasing magnesium availability on the uptake of magnesium with liming was similar to that on the unlimed soil. For ryegrass, the slopes of the uptake curves are markedly different, the rate of magnesium uptake from limed soil being considerably greater for increasing increments of magnesium availability than from unlimed soil. It is interesting to note that the maximum uptake of magnesium from unlimed soil is about the same as the minimum uptake from limed soil for both crops.

The influence of soil pH on the uptake of magnesium is clearly shown in these experiments with sweet corn and ryegrass. Increasing the availability of magnesium without raising the pH did not markedly increase the uptake of magnesium.

II. Effect of Liming and Magnesium Fertilization on the Growth and Absorption of Magnesium by Alfalfa.

The treated soils used in the previous study (1) were divided in half. One-half were limed with calcitic limestone to a pH of 6.5. Alfalfa was grown in these soils and harvested when the majority of plants came into bloom. The uptake of magnesium was determined as for the crops used in Experiment I. The results are given in Table 6 and Figures 4 and 5.

Liming with calcitic limestone increased the yield of alfalfa significantly for all treatments except for number 9. Calcitic liming significantly increased the uptake of magnesium for all treatments except for numbers 8 and 9.

Liming significantly increased the yield of alfalfa (Figure 4) and the uptake of magnesium (Figure 5). Also there was a marked yield response to magnesium additions when the soils were limed to a pH of 6.5. This indicates that liming alone, specifically for alfalfa, with calcitic limestone does have a marked effect on absorption of magnesium. The addition of magnesium alone without a change in soil pH had no significant influence on yield or magnesium uptake.

Summary of Greenhouse Experiments

Liming an acid (pH 5.0) Muskingum soil from Columbiana County usually resulted in a significant increase in magnesium uptake. The addition of magnesium without an increase in soil pH had only a slight effect on the uptake of magnesium. Liming and magnesium soil additions combined markedly increased the uptake of magnesium.

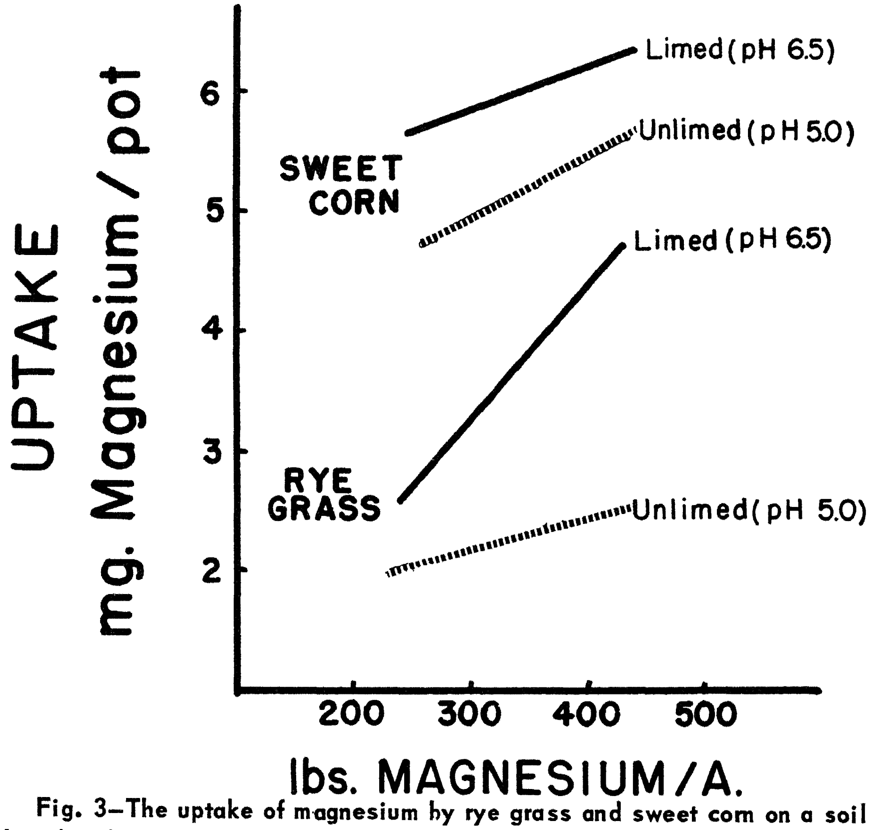

Fig. 3—The uptake of magnesium by rye grass and sweet corn on a soil limed and unlimed with various levels of magnesium availability.

TABLE 6.–Yield and Magnesium Uptake by Alfalfa on a Soil Varying in pH and Magnesium Availability.

Treatment Number	Previous Soil Treatment	Yield of Alfalfa Gms/Pot: No Additional Treatment	Yield of Alfalfa Gms/Pot: Limed to 6.5 with Calcitic Limestone	Magnesium Uptake Mg/Pot: No Additional Treatment	Magnesium Uptake Mg/Pot: Limed to 6.5 with Calcitic Limestone
1	Check (soil pH 5.2)	.23	1.55	1.5	8.2
2	35 lb. of Mg+/A	.40	1.29	2.8	6.6
3	100 lb. of Mg+/A	.21	1.52	2.1	7.5
4	200 lb. of Mg+/A	.36	1.50	2.1	8.6
5	Limed* to pH of 5.6 + 35 lb. Mg+/A	.30	1.12	2.7	8.0
6	Limed* to pH of 5.6 + 100 lb. Mg+/A	.44	1.51	3.2	11.2
7	Limed to pH of 5.6 +200 lb. Mg+/A	.64	1.83	4.8	10.8
8	Limed* to pH 6.0	.99	1.64	6.9	10.0
9	Limed* to pH 6.8	1.77	2.10	12.8	14.5
	Mean	.59	1.53	4.3	9.5
	L.S.D. (.05)	.38		3.23	
	L.S.D. (.01)	.51		N.S.[1]	

*Using dolomitic limestone

+As $MgSO_4 \cdot 7H_2O$

[1]Not significant

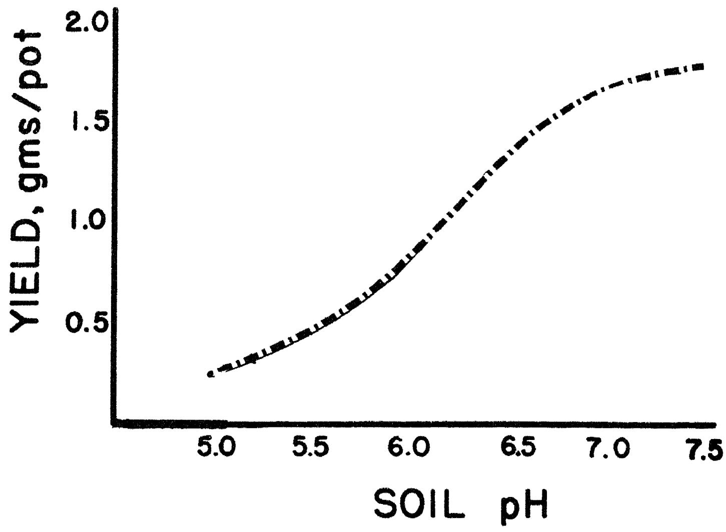

Fig. 4—Yield of alfalfa with increasing soil pH.

On low pH soils, the correction of magnesium deficiency is very difficult if no increase in soil pH is made. This is clearly illustrated in all the greenhouse experiments. Some increase in magnesium uptake can be obtained with magnesium fertilization on the acid soils using magnesium sulfate, however, at low pH's large additions may be necessary to provide adequate available soil magnesium for normal plant development.

PROBLEMS IN MAGNESIUM DEFICIENCY CONTROL

For the potato grower the correction of magnesium deficiency can be a difficult problem. Many growers are not willing to lime for fear of providing conditions for the development of potato scab. Potatoes respond to potash fertilization and many growers are using continuously heavy applications of potash without regard to the increasing soil potassium level. With a low soil pH and an increasing level of available potassium, a magnesium deficiency can develop. Sizeable additions of magnesium (as magnesium sulfate) are needed in order to correct the deficiency quickly. Some of the growers in Columbiana County have resorted to this technique and have obtained a degree of control.

The relationship between soil pH and the incidence of potato scab is not well established for the soils in Columbiana County. Wilson (14) has recently reported that potato scab can be significantly reduced by crop rotation. Incidence of potato scab can be reduced to less than 5 percent when potatoes appear in the rotation only once every three years. Most Columbiana County potato growers rotate potatoes with sweet corn which is not sufficient according to Wilson (14) to bring the incidence of potato scab to a tolerable level.

Magnesium deficiency can be easily controlled by liming with dolomitic limestone. A soil test for magnesium alone is not sufficient to determine if a deficiency condition is present. In addition to the magnesium test, the determination of soil pH and available potassium are essential. Soils with low magnesium availability (less than 200 lbs./acre) and a pH of less than 5.4 or a potassium to magnesium ratio greater than 4 are likely to be magnesium deficient.

Magnesium deficiency in Columbiana County is mainly due to low soil pH and low soil available magnesium. Instances of high potassium and low magnesium availability levels have resulted in deficiency conditions in some areas. Increasing the soil pH and magnesium level by liming using dolomitic limestone or reducing the ratio of potassium to magnesium by fertilizing with magnesium sulfate, can reduce the likelihood of the deficiency occurring.

The extent of the severity of magnesium deficiency may be dependent upon climate In general, temperatures above normal over an extended period or insufficient rainfall during early plant development may induce or intensify a magnesium deficiency condition. The wide occurrence of

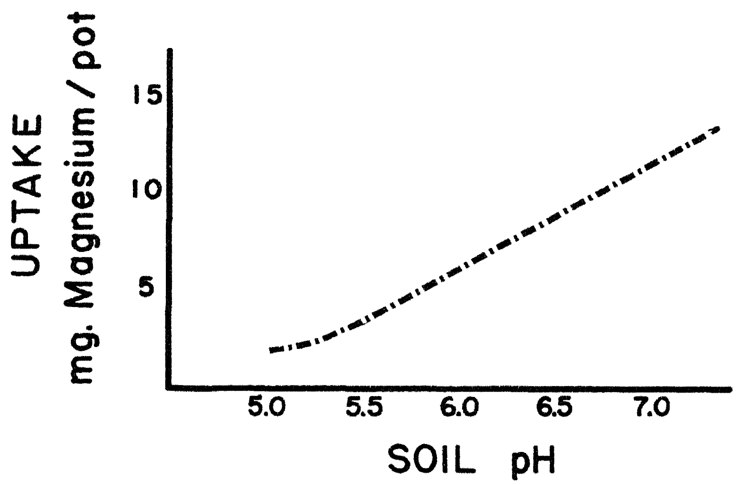

Fig. 5–Uptake of magnesium by alfalfa with increasing soil pH.

magnesium deficiency symptoms in 1959 in Columbiana County may have been due to the above normal temperature experienced during most of June and July.

Of the commonly grown crops in Columbiana County, sweet corn and ryegrass are the most sensitive to a lack of sufficient available soil magnesium, and particularly to the potassium/magnesium ratio. Wheat and potatoes are sensitive to magnesium but to a lesser extent than sweet corn or ryegrass. Some corn hybrids are also quite sensitive to magnesium (12).

Row and spray applications of magnesium sulfate are only temporary means of controlling the deficiency. The maintenance of a proper soil pH, adequate available soil magnesium, and a low potassium to magnesium ratio should provide the means for permanent control. For the potato farmer, crop rotation should be employed to control scab (14). Low soil pH and heavy applications of potassium fertilizer will not always insure best yields and potatoes free from scab. Potatoes are responsive to higher soil pH's (see Table 4) and less nutritional difficulties are likely to arise when a more moderate potassium fertilizer plan is followed accompanied by frequent liming with dolomitic limestone.

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