THE EFFECT OF CALCIUM AND MAGNESIUM ON PLANT GROWTH IN AN ACID COLOMA SAND WITH LOW EXCHANGE CAPACITY

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By

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AN ABSTRACT

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Abstract

This problem was undertaken to determine whether calcium alone, magnesium alone or a combination of these two neutralizing amendments were necessary for the optimum plant growth on the particular soil chosen. The soil for this experiment was an orchard soil of Coloma sand with a pH of 3.8 on which the farmer was experiencing difficulty in growing cover crops except when a magnesium bearing neutralizing agent such as dolomitic limestone was added. The experiment was set up in one-gallon pots containing 4500 grams of dried screened soil. A 3-12-12 fertilizer made up of CP chemicals was added at a rate of 1000 pounds per acre. Part of the soil treatments received only calcium amendments, part only magnesium amendments and the remainder a combination of calcium-magnesium bearing neutralizing amendments. Rates per acre ranged as follows: calcium carbonate, one ton (1 T.) to three tons (3 T.) in one ton increments; magnesium carbonate, the same as $CaCO_3$; and magnesium sulphate, 500 pounds, 1000 pounds and 1500 pounds.

Twenty-five treatments of three replicates each were planted to Henry spring wheat and nine treatments of three replicates each were planted to Rainy River pea beans.

The first trial of the experiment was discarded because of poor germination and a second set up after the soil had been dried, rescreened and remoistened to field capacity. The crops were harvested at the end of seven weeks. By this time the plants in the check cultures were dead and there was an observable difference in the height and the color of growth on both the wheat and bean experiments. Those cultures receiving only small amounts of $CaCO_3$ were weak and chlorotic, becoming sturdier and greener as the $CaCO_3$ was increased. Those plants receiving both $MgCO_3$ and $MgSO_4$ were deepest in color and had the most luxuriant growth.

From the results of the tests run on the soil, as well as from the weight of the dried plant material obtained from the experiment, it would appear that more than three tons per acre of a neutralizing agent would be necessary to raise the pH to an optimum level for plant growth.

When three tons of a neutralizing agent is needed on a soil with a low exchange capacity, it is obvious that something unusual had happened to the soil. It would appear that the continued leaching of fungicides and insecticides applied to the foliage of the trees in the apple orchard may have had an effect upon the basic exchange ions in this soil. It is suggested that a study should be made of the effect of fungicides and insecticides on the soil before recommending that neutralizing agents be applied.

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THE EFFECT OF CALCIUM AND MAGNESIUM ON PLANT GROWTH IN AN ACID COLOMA SAND WITH LOW EXCHANGE CAPACITY

I. INTRODUCTION

With increasing frequency, agronomists concerned with the sandy soils of the glaciated regions of this area have experienced unsatisfactory results from the addition of limestone. These sandy soils have low inherent fertility, not only in the basic plant nutrients nitrogen, phosphorus and potash but also the so-called secondary elements, such as calcium and magnesium. It is safe to assume that the low yields on these acid, sandier soils are due, in part, to a lack of other bases than calcium, perhaps magnesium.

The work reported here concerns a particular orchard problem in Allegan County, Michigan in which the orchardist was having difficulty growing cover crops under or near the trees. The soil was a Coloma sand which had become quite acid (pH 3.8) and had an exchange capacity of 2 ME/100 gms. Ordinary liming practices were not giving satisfactory results in solving the problem so some of the top six inches of soil from under the trees was removed and brought to East Lansing for study in the greenhouse at Michigan State University. It was thought that a study of various rates of application of magnesium and calcium additives, used to correct the pH of the soil, might throw some light on the cover crop problem.

REVIEW OF LITERATURE

Though magnesium deficiencies in plants have been described and recognized for many years (3), it has only been in the past twenty years that much research has been accomplished in finding remedies for these deficiencies. Probably the greatest reason for the delay has been in the complexity of the problem (16). It has been shown that for certain crops there is a definite relationship and ratio between the amount of calcium and magnesium needed (14).

In the 1938 Yearbook of Agriculture (15) a statement is made that magnesium deficiency, in all probability, has affected crop production more widely than any of the other secondary plant foods. Magnesium deficiency has been due primarily to two factors; (1) the use of commercial fertilizers containing very little magnesium, and (2) increased soil acidity resulting in the leaching of the available magnesium from the soil. Thus, the area of sandy soils low in natural magnesium has increased and it is safe to assume that some of this depression in crop yields can be attributed to magnesium deficiency. It has been known for some time that limestone and other calcium additives used by many farmers, especially on these sandy soils, has been of a type containing no magnesium, namely, calcitic limestone and marl. It has been shown that many problems are encountered when

secondary plant nutrients are deficient, the plant showing deficiency symptoms of many kinds (10). To further confuse the problem, the plant becomes weaker and much more susceptible to disease and insect damage. A deficiency of magnesium may be accompanied by a more rapid uptake by the plant of the available potassium in the soil and, when the magnesium deficiency has been corrected, there may be a deficiency of potassium shown (6). Another reason for investigating magnesium and calcium deficiency under orchard conditions is that acidifying fungicides and fertilizers may cause leaching of replaceable calcium, magnesium and potassium at a much faster rate and to greater depths than under ordinary agricultural crops (4, 8).

Magnesium is one of the elements essential to plant growth (19) and as yet it's role in plant constituents and processes have not been fully established (7). It has been found to be a part of the chlorophyll molecule; to be a carrier of phosphorus and to assist in initiating new growth (5). Magnesium deficient plants are more susceptible to disease than are normal plants (2).

The amount of magnesium found in the soil is often referred to as relative to the amount of calcium present, i.e. Ca:Mg ratio (1, 10, 14). It has been found that the optimum ratio for most agricultural crops is approximately 6:1.

Magnesium is the most difficult divalent cation to displace from the soil complex (13). Therefore, conditions of the soil must be known in order to correctly evaluate the results of soil analyses (12, 17).

The literature on the effect of availability of plant nutrients at various levels of calcium and magnesium in the soil is extensive (1, 9, 10, 11, 12, 18). The research findings on the effect of calcium and magnesium on the availability of the other nutrients has been both controversial and confusing. Prince, Zimmerman, and Bear (13) did research on twenty different New Jersey soils ranging in pH from 4.8 to 6.6. These workers found that in acid soils the addition of calcium and magnesium tended to inhibit the release of adsorbed ions, while in alkaline soils the reverse was true. This work tended to remove much of the confusion in the field.

Research findings in the field of orcharding are of interest. Gourley (8) found that excesses of fungicidal and insecticidal sprays washed from the orchard foliage had a serious effect on the balance of the soil nutrients, especially in samples taken from under the trees. Boynton and Magness (4) stated that fungicide and insecticide spray residues definitely accelerate the rate of leaching of cations in orchard soils.

PROCEDURE AND DISCUSSION

Soil was obtained in the late spring of 1952 from an unlimed area in an old apple orchard both from under the trees and between the rows and brought to the Soil Science laboratory at Michigan State University where it was air dried and screened through an 1/8-inch mesh screen. Four thousand five hundred grams of the screened soil was placed in each of the one-gallon glazed pots. A 3-12-12 analysis fertilizer made up of chemically pure ingredients was added at the rate of 1000 pounds per acre. Henry spring wheat and Rainy River pea beans were grown. They were chosen because of their susceptibility to magnesium deficiency. Twenty-five different soil treatments were applied where the Henry spring wheat was planted and nine treatments where Rainy River pea beans were grown. The treatments were replicated three times.

The treatments, stated on an acre basis, were as follows:

	Pounds per acre		
	$CaCO_3$	$MgSO_4$	$MgCO_3$
1.	0	0	0
2.	2000	0	0
3.	4000	0	0
4.	6000	0	0
5.	2000	500	0

Pounds per acre

	$CaCO_3$	$MgSO_4$	$MgCO_3$
6.	4000	500	0
7.	6000	500	0
8.	2000	1000	0
9.	4000	1000	0
10.	6000	1000	0
11.	3000	500	0
12.	3000	1000	0
13.	3000	1500	0
14.	0	500	3000
15.	0	1000	3000
16.	0	1500	3000
17.	0	0	2000
18.	0	0	4000
19.	0	0	6000
20.	0	500	2000
21.	0	500	4000
22.	0	500	6000
23.	0	1000	2000
24.	0	1000	4000
25.	0	1000	6000

The soil treatments for the Rainy River pea beans were as follows:

	Pounds per acre		
	$CaCO_3$	$MgSO_4$	$MgCO_3$
1.	0	0	0
2.	2000	0	0
3.	4000	0	0
4.	6000	0	0
5.	2000	1000	0
6.	4000	1000	0
7.	6000	1000	0
8.	0	0	2000
9.	0	0	4000
10.	0	0	6000

Thirty seeds of the Henry wheat and nine seeds of Rainy River pea beans were planted per pot in June of 1952. The germination of the pea beans was so poor that this part of the experiment was discarded. Two weeks after planting there was an observable magnesium deficiency in the plants in some of the cultures but these deficiencies were so completely at random that it was suspected that the additives were not thoroughly mixed with the soil and the plants had not reached the added nutrients. At the end of this two-week period the plants in the check cultures were dying after reaching a height of approximately two inches.

At the end of four weeks the magnesium deficiencies which were observed at the end of two weeks were now completely gone. The plants in the check cultures were completely dead.

Six weeks after planting, observable differences appeared due to treatments. The plants where treatments 2 through 8 were used showed a gradual increase in height of growth and generally were healthier in appearance. The plants given treatment 11 showed a shorter but more dense growth than those in treatment 5. Those cultures where treatments 12 through 16 were applied showed a gradual increase in growth over those where treatment 11 was used. The plants growing in pots where treatments 17 through 25 were applied showed the same gradual increase in height of growth as did their counterpart treatments 2 through 10, except that those in the $MgCO_3$ treated group showed better color and more uniform heading of the grain than did those which received $CaCO_3$.

The extreme temperatures of the greenhouse during the summer months were not conducive to good plant growth, and the wheat experiments were harvested at the end of seven weeks.

The soil was dried thoroughly and again screened in preparation for a second run of the same experiment. After replacing the soils in the same pots, water was added to bring the soil to field capacity. The water did not enter the soil normally and it appeared that the soil was completely deflocculated, even though it was single grained. After four days the water and soil were mixed by hand. No further amendments were added for this second crop.

The wheat and the pea beans were planted in August of 1952 in a similar manner as described before. This second experiment proved much more satisfactory so far as germination was concerned for both the beans and the wheat.

At the end of the two-week period after planting, the plants in the check cultures were showing signs of multiple deficiencies and were dying. There were no observable magnesium deficiencies in any of the other cultures but there was a slight difference in color. The plants treated only with calcium carbonate were much lighter in color than those which received magnesium, either as magnesium sulphate or magnesium carbonate.

At the end of four weeks, some observable differences were noted in height of growth. The plants in the check cultures were nearly dead.

At the end of six weeks from planting there appeared in both the wheat and the beans the same observable differences mentioned during the first experiment.

The wheat and the beans were harvested at the end of seven weeks. The harvested plants were left to air dry for fourteen days in the greenhouse and then were placed in an oven for forty-eight hours at eighty-five degrees (85°) centigrade and weighed.

Samples of soil were taken from each pot and tests were run on these samples, the results of which are shown in the tables on the following pages. The addition of the various amounts of calcium and magnesium additives in no case raised the pH to anticipated levels. The addition of 1000 and 1500 pounds of magnesium sulphate tended to depress pH although this was not significant. The tests made were run by the modified Spurway quick test method (12).

Table 1. Results of tests on the untreated soil before and after the experiment

Soil	pH	Pounds per acre available plant food			
		P	K	Ca	Mg
Before	3.8	17	25	160	B
After	3.8	22	26	160	B

Table 2. The effect of magnesium carbonate, magnesium sulfate and calcium carbonate on soil tests and yield of Henry spring wheat

Pounds per acre			pH	Pounds of available plant food per acre				Grams tissue* (dry wt.)
$CaCO_3$	$MgSO_4$	$MgCO_3$		P	K	Ca	Mg	
0	0	0	3.8	22	26	160	B**	less than 1
2000	0	0	4.4	26	40	300	B	8.5
4000	0	0	4.9	19	32	420	B	11.0
6000	0	0	5.2	21	38	650	B	17.0
2000	500	0	4.3	17	42	400	10	11.5
4000	500	0	5.0	14	46	510	16	15.0
6000	500	0	5.4	16	36	750	38	13.0
2000	1000	0	4.6	12	48	400	38	13.5
4000	1000	0	5.0	18	50	475	36	14.5
6000	1000	0	5.5	15	54	680	44	14.0
3000	500	0	4.3	17	47	440	15	13.0
3000	1000	0	4.6	14	41	460	35	12.5
3000	1500	0	4.9	11	55	430	41	15.0
0	500	3000	4.5	13	61	430	42	13.0
0	1000	3000	4.8	15	56	380	44	14.5
0	1500	3000	5.2	12	54	410	56	14.5
0	0	2000	4.5	17	44	320	23	10.5
0	0	4000	4.9	21	41	350	27	13.0
0	0	6000	5.5	19	43	300	42	18.5
0	500	2000	4.5	16	50	280	38	11.0
0	500	4000	5.1	17	53	310	47	14.0
0	500	6000	5.3	13	47	290	54	16.0
0	1000	2000	4.6	13	61	430	31	13.0
0	1000	4000	5.0	15	58	320	49	18.0
0	1000	6000	5.6	10	66	340	56	19.5

*Total from 3 cultures
** B - blank

Table 3. The effect of magnesium carbonate, magnesium sulfate and calcium carbonate on soil tests and yield of Rainy River pea beans

Pounds per acre			pH	Pounds of available plant food per acre				Grams tissue* (dry wt.)
$CaCO_3$	$MgSO_4$	$MgCO_3$		P	K	Ca	Mg	
0	0	0	3.9	17	24	160	B**	less than 1
2000	0	0	4.3	20	30	230	B	6.5
4000	0	0	4.8	16	32	320	B	10.0
6000	0	0	5.3	20	29	280	B	9.0
2000	1000	0	4.4	14	35	400	41	8.0
4000	1000	0	4.9	14	[illegible]	300	47	14.0
6000	1000	0	5.4	12	41	540	42	14.5
0	0	2000	4.6	16	37	410	39	13.0
0	0	4000	5.0	18	43	330	43	19.0
0	0	6000	5.7	19	36	320	44	19.5

*Total from 3 cultures
**B - blank

Figure 1. The beans on the left received $CaCO_3$ at the rate of 6000 pounds per acre, while the more vigorous and darker colored plants on the right received 3000 pounds of $CaCO_3$ and 1000 pounds of $MgSO_4$ per acre.

SUMMARY

Two crops, very sensitive to the amount of magnesium available in the soil, were grown in the greenhouse to determine the effects on plant growth by varying the calcium-magnesium ratio in the soil. The soil was Coloma sand that had been in an apple orchard for over twenty years. The pH, 3.8, and the exchange capacity, 2 m.e. per 100 grams, was extremely low.

Very poor germination was experienced with the bean experiment and on about one-half of the wheat cultures in the first trial. The poor germination was not associated with treatment. Due to this poor germination, the experiment was rerun.

The plants in the check cultures which received only the fertilizer lived about two weeks in this acid soil. These plants showed evidence of multiple deficiencies very soon after emergence. There was a gradual increase in height of growth of the plants as the calcium and magnesium amendments were increased. The plants which received the high amounts of magnesium had a much greener color than those which received only calcium.

The data may be summarized as follows:

1. The calcium and magnesium levels had been reduced in the soil either by leaching, crop removal, or interaction of added spray residues so that plant

growth was seriously affected.

2. The addition of calcium to this soil improved plant growth.

3. The addition of three tons of magnesium carbonate plus 1000 pounds of $MgSO_4$ resulted in what appeared to be the best plant growth and best plant color.

4. The addition of three tons of neutralizing amendments was not enough to bring this soil to the desired pH.

5. The effects of continued applications of fungicides and insecticides on orchard soils should be studied before correct recommendations can be made for neutralizing amendments on such soils.

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