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# A Study of the Effects of an Excessive Ratio of Lime to Magnesia Upon Plant Growth

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To the Graduate Council:

I am submitting herewith a thesis written by John Ira Hardy entitled "A Study of the Effects of an Excessive Ratio of Lime to Magnesia Upon Plant Growth." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agriculture and Extension Education.

W. H. MacIntire, Major Professor

We have read this thesis and recommend its acceptance:

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Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

# THESIS.

A STUDY OF THE EFFECTS OF AN EXCESSIVE RATIO OF LIME TO MAGNESIA UPON PLANT GROWTH.

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of SCIENCE in AGRICULTURE.

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## INTRODUCTION.

For centuries the beneficial effects derived from the agricultural use of lime have been known, its use being common among the chinese long before the Christian era. Pliny, writing more than two thousand years ago, described the use of chalk by Roman farmers. In some parts of England and Western Europe lime has long been regarded as next to manure as a fertilizer. Although the use of lime in this country was recorded and recommended by Johnston,[I] more than a hundred years ago, only during the more recent years has the subject of liming been investigated by scientific experiments and its relation to different phases of crop production carefully studied. The beneficial effects of lime treatments were at first attributed to the value of the element calcium as a plant food, and were not regarded as a means of amelioration of unfavorable soil conditions.

## STUDIES OF THE FUNCTION OF LIME IN PLANT GROWTH.

In studying the functions of lime and magnesia in plant growth, Loew and May[2] concluded from their experiments that "lime is necessary for the formation of certain calcium compounds of nucleo-proteids required in the organized structures of nuclei and chlorophyll bodies, while the magnesia serves for the assimilation of phosphoric acid, since magnesium phosphate can give up its phosphoric acid more easily than any other phosphate that occurs in plant juices. While Calcium is fixed in the organized structure, magnesium is movable since it serves mainly in the form of secondary phosphate as a carrier of assimilable phosphoric acid, which role can be repeated at various times." Loew further states, "that in the case of an excess of lime being taken up, the assimilation of phosphoric acid will be rendered more difficult, since this acid will chiefly combine with lime and the chance for the formation of magnesium phosphate will then be diminished. The effect will be the same as if the amount of available phosphoric acid in the soil were lessened---that is, the growth of the plant will be retarded and even starvation phenomena may set in".

Considered from the view point of nutrition, this hypothesis of Loew and May is a plausible explanation of the benefits derived from lime and of the ill effedts of excessive lime treatments, but the marked benefits accruing from applications of lime are generally attributed to betterment of soil physical conditions, improved tilth and texture and the extablishment of an alkaline soil medium enabling the beneficial soil bacteria to better perform their functions, as well as liberating plant food from some of the more insoluble zeolitic and phosphatic combinations.

EXTENT OF APPLICATION OF LIME IN PRACTICE.

Though the practice of liming is very old and its beneficial effects have been well extablished among the more progressive men in agriculture, there is some difference in opinion as to the amount of lime which may be judicially applied and whether a limestone containing but a very small percentage of magnesia is more desirable than one rich in magnesia occurrence.

Loew advanced the hypothesis that plants function best when the soil occurrences of lime and magnesia are maintained in a definite ratio. As a result of many pot experiments with both sand and soil as media, Loew and his colleagues in Japan concluded that his hypothesis had been substantiated and that the most favorable ratio of lime to magnesia in practice is expressed by that of 2 to 1. On the other hand Meyer[4] as well as Limmerman, Ernicke and Fisher,[5] from extensive pot experiments concluded that there is no close relationship between lime to magnesia ratio and maximum soil fertility.

In England according to Hall[6], lime was often applied at the rate of four, six or eight tons per acre and while regarded as having a somewhat harmful effect in the larger applications, the heavy treatments at long intervals were regarded as being most economical in both time and labor. Even at the present day many farmers having an abundance of lime rock make enormous applications of the ground lime stone, expecting increased benefits in proportion to the extent of treatment, at the same time extending the periods between liming.

OBJECTS OF EXPERIMENTS HEREIN REPORTED.

It was with the idea of determining the effects of excessive liming and to study the influence of an excessive ratio of lime to magnesia upon growth of four crops, namely, alfalfa, barley, clover and sorrel, that the experiments here reported were planned.

As has been given above, Loew and May state that, "with excess of lime over magnesia the physiological action of the plant is hindered and it exhibits phenomena of starvation." Aso,[7] Yokoyama,[8] Kanomata,[9] Takenchi,[10] Bernardini and Corso,[12] Kanamori,[11] Kumakira,[13] Konovalov,[14] Daikuhara,[15] Katoyama,[16] and Nakumara,[17] substantiate the theory of Loew[18] in their work in pot cultures, finding the lime and magnesia ratio varying with the crops under experiment and the fineness and source of the magnesium treatments.

In order to make conditions extreme and severe, it was planned to have plant growth subjected to pure limestone and pure sand, with intermittent percentages, the essential plant food furnished to each pot being identical throughout for each crop.

While it is realized that the use of sand as a medium instead of soil does not offer conditions entirely identical with those of the field, the use of soil would involve the factors of varying plant food and physical conditions. It is probable that less of lime may be dissolved from the limestone and sand mixtures than would be present in a calcareous soil containing very much less lime, but more of $CO_2$ solution from decaying organic matter. Much care was taken to produce uniformity in the physical conditions of all treatments, the lime and sand being of practically identical density and fineness, 1/2 to 1 mm.

The crops were chosen with reference to their fondness for lime, clover and alfalfa being taken as plants doing best in alkaline media and especially fond of lime. Barley was chosen as a plant requiring less of lime, while sorrel was taken because of its ability to withstand the conditions existing in acid soils. The following diagram shows ~~percentagely~~ the proportions by percentage of ground-limestone to sand in treatments:

PLAN OF POT CULTURE EXPERIMENT.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Limestone: | 100% | 75% | 50% | 25% | 15% | 5% | 2.5% | 1% | .5% | 00% |
| Sand | 00% | 25% | 50% | 75% | 85% | 95% | 97.5% | 99% | 99.5% | 100% |
| Alfalfa | A-1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Barley | B-1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Clover | C-1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Sorrel | S-1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

DETAILS OF POT WORK.

The experiments were carried on in eight inch clay pots. The holes in the bottoms of the pots being corked and the pots then treated with two coats of black asphaltum, so that there would be no error resulting from osmosis when the pots containing the various treatments were imbedded in the soil. These pots were filled with a definite constant aggregate for each pot, of sand and limestone, well mixed in the proportions shown. The mixture of sand and limestone varied from pure limestone in pots numbered one to pure sand in those marked ten, the aggregate weight in each case being 5670 grams. The sand of very uniform fineness was obtained from a river bottom and contained but very little organic matter. After drying the sand thoroughly on a hot plate it was all passed through the one M.m. sieve. In this condition the ground limestone and sand were nearly identical in density as determined by a pyknometer. The density of the sand being considered as one, the limestone was found to be 1.001.

It has been found that in the South where the heat is intense during the hottest months, that it is highly advantageous to embed the pots in the ground when conducting pot experiments. They are in this way kept cooler and the evaporation is much nearer to what it would be under normal conditions. Experience with wire baskets such as are used by the Bureau of soils[19] has shown that they are not adapted to the intense heat of the Southern States. While the cans used by the Hawaii Station[20] were considered, it was thought that earthenware pots treated in the manner described would be better suited to the given conditions.

SEEDING OF CROPS.

The crops were all seeded April second, 1913, and to a depth of 3/4 inches except the sorrels which were seeded to a depth of 1/4 inch. A good growth of barley was readily obtained, but the alfalfa and clover were very slow and uneven in starting. These last two crops were re-seeded May 2nd, coming up this time very evenly. The sorrels germinated, but were very slow in making any growth at all, and on June 13th they had grown only about 1/8 inch. There were a great many of the sorrel plants, but on account of the slowness of their growth, stoles were obtained as nearly as possible uniform in size and eight of these were planted in each pot.

PLANT FOOD APPLIED.

Eleven and four-tenth grams of magnesium corbonate, representing a treatment of .2% were added to $A-_{10}$ $B-_{10}$ $C-_{10}$ $s_{10}$, the pots containing pure sand without any ground limestone or lime salts.

Phosphoric acid was supplied to each pot by adding 12.39 grams of precipitated tri-calcium phosphate (C.P.), representing a treatment of .1% $P_2O_5$ which was thoroughly incorporated, in the dry mixtures before being placed in the pots. The other elements essential for plant growth were made into a stock solution composed of $KNO_3$, $K_2SO_4$ and Kcl in the correct proportions for plant growth. The iron impurities in the stone and sand were considered as sufficient without any supplementary iron treatments.

The following table shows the soluble plant food furnished each pot of each crop for its entire period of growth together with the insoluble forms of treatments.

| | Barley | Alfalfa | Clover | Sorrel |
|---|---|---|---|---|
| Per pot | 1.5g $KNO_3$ | 1.125g $KNO_3$ | 1.125 $KNO_3$ | .875 $KNO_3$ |
| " " | 4.5g $K_2SO_4$ | 3.375 $K_2SO_4$ | 3.375 $K_2SO_4$ | 2.625 $K_2SO_4$ |
| " " | .225g Kcl | 1.6875 Kcl | .1687 Kcl | .1313 Kcl |
| " " | 1239 $Ca_3P_2O_8$ | | | |

PLATE I.

BARLEY.

PLATE II.


BARLEY

$B_I$ 1.35g $B_2$ 1.25g $B_3$ 1.25g

PLATE III.


BARLEY.

| Air Dry Wt. of Root and Top Development | $B_4$ | $B_5$ | $B_6$ | $B_7$ | $B_8$ | $B_9$ | $B_{10}$. |
|---|---|---|---|---|---|---|---|
| | 5.14g | 2.56g | 6.10g | 6.56g | 9.57g | 13.46g | 13.20g |

WINTER BARLEY.

Wheeler and Tillinghast[21] in their experiments on plant adaptation have shown that barley was benefitted by liming in certain Rhode Island soils. It is quite possible that these soils giving a very marked increase in barley after liming were very deficient in lime. The results of the Rothamstead experiments[22] on liming indicate that lime is beneficial to barley when applied in small amounts, though the reported increased yields are not extensive.

Plate One shows the barley plants photographed May 2nd, one month after seeding. The growth is greatest in pots $B_7$, $B_8$, $B_9$, $B_{10}$, containing the smallest amounts of lime; while the pots containing more lime were not as rugged in appearance as the others, being of a slight yellowish tint. A similar color was reported by Loew and May[18] in recording the results of their experiments upon the growth of barley in media containing excess of $M_g\ CO_3$. They attributed this yellowish appearance to Chlorosis.

For the next ten days there seemed to be a gradual cessation of growth and the plants became somewhat sickly looking. Believing this might be due to a lack of sufficient nutrient solution, the writer gave them an application, to which those plants in pots containing less of lime responded, while there were no beneficial effects on $B_1$, $B_2$, $B_3$. These three pots were harvested and photographed May 17th. Plate II shows the extent of root and top development at this time.

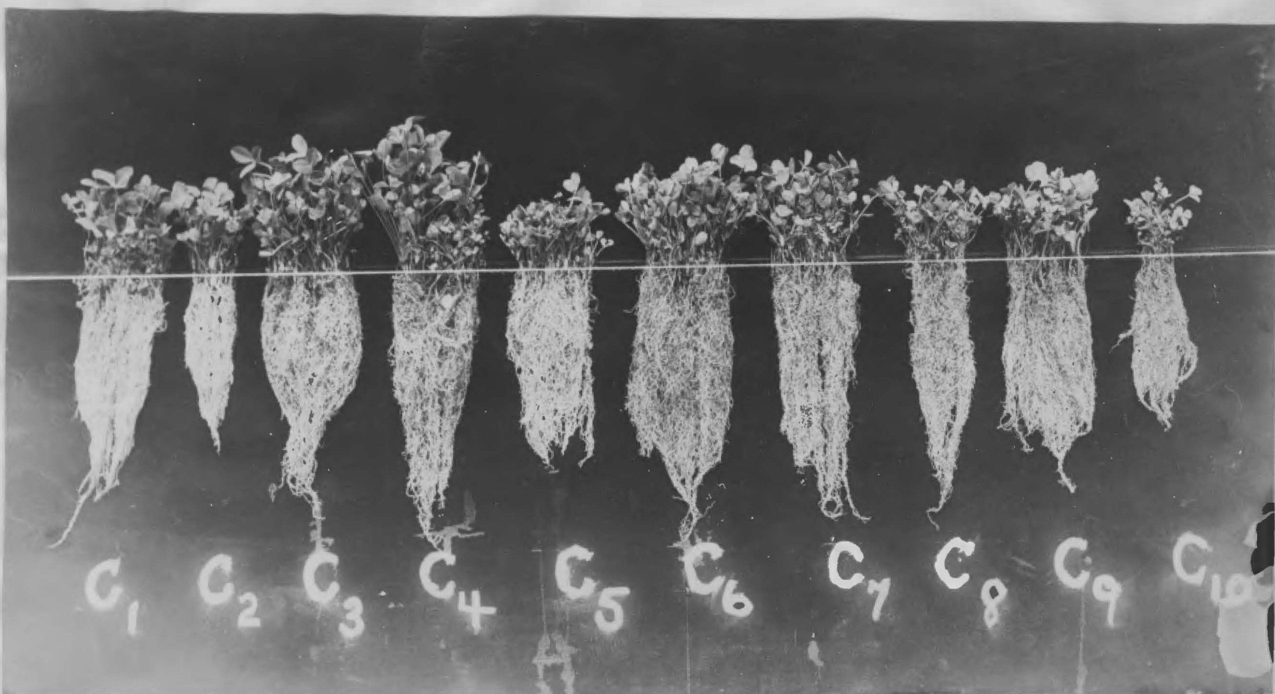
The Barley in the remaining seven pots continued to grow until

June 4th, when it had practically ceased growing, and on this day it was harvested. At the time of seeding, spring barley could not be readily obtained, and a winter barley was substituted for the Spring variety. It is possible that the extent of growth was affected by the use of winter barley as well as by treatment.

PLATE IV.


CLOVER.

PLATE V.




CLOVER.

| Air Dry Wt. of Root and Top Development | C-1 | C-2 | C-3 | C-4 | C-5 | C-6 | C-7 | C-8 | C-9 | C-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3.69g | 3.70g | 4.68g | 4.48g | 3.28g | 4.86g | 3.99g | 2.88g | 3.69g | 1.78g. |

## RESISTANT RED CLOVER.

It has been shown by extensive experiments that clover responds exceedingly well to liming. In the pot experiments red clover resistant to Anthracnose was grown. In Plate IV is shown the extent of growth attained by July 22nd 23, a little less than eleven weeks from the date of seeding. The growth is decidedly in favor of Pots $C_3$ and $C_4$ containing 50% and 25% of ground limestone respectively. Although this seems a very great excess of limestone, it must be borne in mind, as previously explained, that the per cent of limestone dissolved in in pot experiments in the absence of $CO_2$ is probably not very excessive. Under field conditions with the soil highly impregnated with $CO_2$ the per cent of ground limestone in solution would be very materially increased.

Plate V shows the growth attained by the clover plants at the time of harvesting, July 23rd.

It can readily be seen that the pots receiving the heavier percentages of lime show the best growth in clover plants, while growth is very slight in the pure sand receiving $MgCO_3$ but no limestone. Some of the plants in every pot showed inoculation with the exception $C_2$ which have no nodules. This inoculation was accidental, bacteriological influences not being considered in the plan of experiment.

PLATE VI.


ALFALFA.

PLATE VII.


Wt. of Air Dry Roots and Top Development.

ALFALFA.

| A-1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 2.88g | 2.37g | 1.96g | 1.98g | 2.09g | 1.64g | 2.99g | 3.61g | 5.25g | 3.16g |

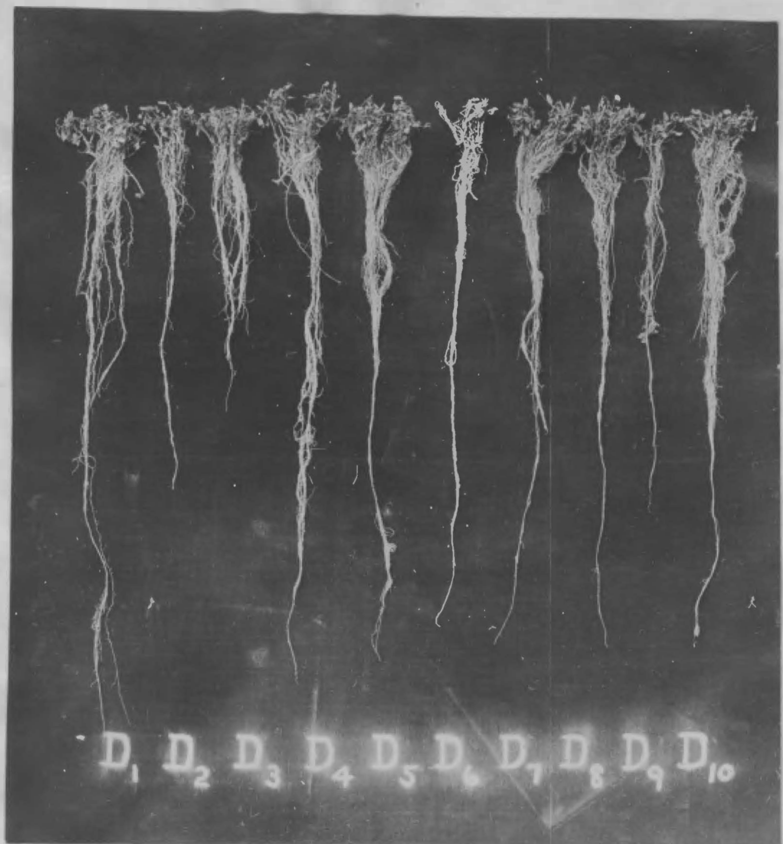
## ALFALFA.

Alfalfa as well as clover requires much lime to enhance the conductivity of nucleo proteids during plant growth. Under field conditions lime plays an important part in neutralizing acid soils, but in what degree of alkalinity the best growth of alfalfa is produced has yet to be determined. From the growth of alfalfa in these pots, where there is not the acidity factor to be found in the field, we may form some idea as to the alkalinity best suited to alfalfa.

Every pot showed inoculation as indicated by nodules, to a greater or less degree. Pots $A_7$, $A_8$, $A_9$, showed good inoculation. $A_2$ and $A_4$ were fairly well inoculated, while $A_1$, $A_3$, $A_5$, $A_6$, $A_{10}$ were inoculated to a lesser extent.

As is shown by the weights of the Alfalfa plants given under Plate VII, the greatest weights are to be formed on the pots containing the smaller percentages of lime, $A_7$, $A_8$, $A_9$ containing 2.5%, 1% and .5% of lime respectively. In pots $A_9$ the increased weight is caused by there being three or four very hardy plants, though there were not as many plants as there were in either $A_7$ or $A_8$. This can be seen from Plate VI.

PLATE VIII.




Wt. of air dry Root and Top development of sorrel plants.

SORRELL.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 1.61g | .42g | 1.06g | 1.91g | .75g | 1.83g | 1.48g | 1.24g | .51g | 1.82g. |

## SORREL.

For years sorrel (Rumex Acetosella) has been considered by many as an indication of soil acidity, because of the failure of clover to thrive, as a rule, where sorrel grows. Though sorrel is uncommonly found growing in good stands of a clover, the writer has observed sorrel and clover plants of rugged growth so close together that their roots probably intertwined, but they were not crowded by other neighboring plants. In the work reported by Tacke [24] abundant growths of sorrel are recorded as having grown on land very heavily limed with marl. Plate VII shows the sorrels harvested September 22nd, after six months growth, with plants growing in the pure limestone apparently as rugged as those in pure sand.

The writer planned to analyze all of the crops for calcium and magnesium, but it was impossible to completely to free the roots of lime held mechanically in the case of barley, clover and alfalfa, to furnish enough of dry matter for checked analyses, from which conclusions would be justified.

## SUMMARY.

When essential plant food, other than calcium and magnesium was supplied in the same amounts to each treatment, good growths of four crops were maintained in 100% ground limestone and in gradations down to 100% of sand.

In growing legumes no improvement resulting from excessive amounts of lime was observed.

No differences were noticed in the barley except in 100%, 75% and 50% ground limestone, where chlorosis developed.

When Optimum plant food treatments were supplied, excess of lime did not affect the growth of sorrel (Rumex Acetosella).

The work indicates that excessive lime treatment, as affecting plant growth, has no claim as a beneficial practice.

Inoculation, as observed in eighteen out of twenty cases, was accidental.

There appeared to be no relationship between the percentage of lime and the degree of inoculation.

The work gives ground for the conclusion that the growth of sorrel in acid soils is due to its ability to resist acid conditions, which are harmful to the growth of legumes but conducive to good growths of sorrel when unhampered by vigorous stands of clover.

The work furthermore parallels that of Gile[25] and suggests that in media where $CO_2$ occurrences are not excessive, that an excess of lime over magnesia is not inhibitory to plant growth where other elements are given in a balanced solution.

All four crops grew fairly well where magnesium carbonate was present without any added lime, except that carried by the tri-calcium phosphate.

Approved.

W. H. MacIntire.

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