THE RELATION OF LIME TO THE ABSORPTION OF IRON BY PLANTS.

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Much attention has been given recently to the relation that iron bears to chlorosis in plants. That the assimilation of iron is closely associated with the proper development of chlorophyll seems to be well established. The addition of ferrous sulphate to the medium in which chlorotic plants are growing has been reported to correct this condition. Westgate and Johnson[1] reported that chlorotic pineapples were brought back to normal condition by spraying with a solution of ferrous sulphate. Korstian, Hartley, Watts, and Hahn[3] have accomplished similar results on conifers.

It has also been noted that the soil conditions developed by excess liming of soils tends to develop chlorosis in plants.[2,5] The observations made by the writer at a number of agricultural experiment stations warrant the same conclusion. The fact that iron precipitates as an insoluble hydroxide in an alkaline solution has led to the theoretical conclusion that the excessive use of lime causes iron to be precipitated from the soil water as an hydroxide, and hence to become unavailable for plant absorption. A prevalent belief seems to be that lime-induced chlorosis in plants is brought about in this manner. An excessive use of lime locks up the iron as an insoluble compound in the soil and renders it unavailable for plant use in the normal development of chlorophyll.

It is not the purpose in this paper to contend that calcium carbonate bears no relation to chlorosis in plants, but that the conditions obtained by the addition of excessive amounts of calcium carbonate do not render iron in the soil unavailable for plant absorption. Tests for iron at the nodes of growing corn plants indicate that plants are able to get rather large quantities of iron from the soil where large and continuous applications of lime have been used.[4] The addition of lime,

[1] Westgate, J. M. and Johnson, M. O. The spraying of yellow pineapple plants on manganese soils with iron sulphate solutions. Hawaii Agr. Exp. Sta. Press Bul. 51. 11 p. 1916.

[2] Gile, P. L. and Carrero, J. O. Cause of lime-induced chlorosis and the availability of iron in the soil. Jour. Agr. Res. 20:33-59. 1920.

[3] Korstian, Clarence F., Hartley, Carl, Watts, Lyle F., and Hahn, Glen G. A chlorosis of conifers corrected by spraying with ferrous sulphate. Jour. Amer. Res. 21:153-171. 1921.

[4] Hoffer, G. N. Testing corn plants chemically to aid in determining their food needs. Purdue Agr. Exp. Sta. Bul. 298:1-31. 1926.

[5] Gilbert, Basil E., McLean, Forman T., and Hardin, Leo J. The relation of manganese and iron to a lime-induced chlorosis. Soil Science 22:437-445. 1926.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

in no instance, seemed to reduce the amount of iron found at the nodes of the plant, but rather to the contrary, to increase it to rather marked degree.[4] The findings have not been construed to mean that the total amount of iron absorbed by the plant is increased by the excessive use of lime. There is some evidence on record, however, to support this conclusion.[5]

The conclusions reached in this paper are the result of data acquired by tests made on corn plants selected from fertility plots at agricultural experimental stations. The plots tested have a definite fertility history and have been running in many instances from 20 to 30 years. The potassiam thiocyanate method was used in determining the amount of iron deposited at the nodes of the plants. This method used is not strictly quantitative; however, differences between light and heavy deposits of iron can be discerned with very little difficulty.[4]

Field Data. The relative amounts of iıon found at the nodes of corn plants grown under various treatments are shown in the accompanying tables. These data represent the typical findings of the field work. Four representative stalks were selected from each plot for the tests. The approximate acidity of the surface soil was obtained by the use of brom thymol blue as an indicator. Space does not permit the introduction of all data obtained by these tests.

TABLE I. Relative amounts of iron found in nodes of corn grown under various treatment at the Pennsylvania State College, State College, Pennsylvania.

Plot	Fertilizer Treatment	Lime Treatment	Approximate Acidity	Indication of relative amts. iron at nodes.
1	48 lb. P_2O_5	Limed	Neutral	**
2	100 lb. K_2O	Limed	Slightly Acid	*
3	48 lb. P_2O_5 24 lb. Dried Blood	Limed	Neutral	***
4	48 lb. P_2O_5 100 lb. K_2O	No Lime	Slightly Acid	*
5	8 T. Manure	Limed	Slightly Acid	—
6	48 lb. P_2O_5 100 lb. K_2O	Limed	Slightly Acid	—
7	72 lb. Dried Blood 48 lb. P_2O_5 100 lb. K_2O	Limed	Slightly Acid	*
8	Check	Burnt Lime	Slightly Alkaline	****
9	Check	None since '23	Slightly Acid	**

— indicates mere trace of iron.
*'s relative larger amounts of iron.

TABLE II. Relative amounts of iron found in nodes of corn grown under varying treatments at the University of Delaware, Newark, Delaware.

Plot	Fertilizer Treatment	Lime Treatment	Approximate Acidity	Indication of relative amounts iron at nodes
10	None	(*) Lime	Neutral	***
11	10 T. Manure every four years	Lime	Neutral	*
12	150 lb. P_2O_5; 5 T. Manure every 4 yrs.	Lime	Neutral	*
13	35 lb. Cyanimid 36 lb. K_2O	Lime	Neutral	*
14	10 lb. $NaNo_3$ 10 lb. $(NH_4)_2 So_4$ 20 lb. D. Blood 150 lb. P_2O_5; 36 lb. K_2O	Lime	Neutral	—
15	None	Lime	Neutral	***
16	20 lb. Dried Blood 200 lb. P_2O_5 48 lb. K_2O 20 lb. $NaNo_3$	Lime	Slightly Acid	—
17	15 lb. Blood; 15 lb. $NaNo_3$ 150 lb. P_2O_5; 36 lb. K_2O	Lime	Neutral	—
18	30 lb. $NaNo_3$ 36 lb. K_2O	Lime	Neutral	—
19	150 lb. P_2O_5 36 lb. K_2O	Lime	Slightly Acid	—
20	None	Lime	Neutral	***
21	60 lb. Fish Scrap 125 lb. P_2O_5	Lime	Neutral	***
22	36 lb. K_2O	Lime	Neutral	*
23	36 lb. K_2O	No Lime	Slightly Acid	—
24	150 lb. P_2O_5	Lime	Neutral	****
25	15 lb. $MaNo_3$ 15 lb. Blood	Lime	Neutral	***
26	None	Lime	Neutral	****
27	None	No Lime	Slightly Acid	**

*Limed plots have received 1,500 lbs. hydrate of lime respectively every four years.

TABLE III. Relative amounts of iron found at nodes of corn grown under varying treatments at the University of Kentucky, Lexington, Kentucky.

Plot	Fertilizer Treatment	Lime Treatment	Approximate Acidity	Indication of relative amts. iron at nodes.
28	100 lb. P_2O_5 Crop Residue	(*) Lime	Neutral	**
29	100 lb. P_2O_5 Crop Residue	No Lime	Medium Acid	—
30	100 lb. K_2O Crop Residue	Lime	Neutral	*
31	100 lb. P_2O_5; 100 lb. K_2O Crop Residue	Lime	Medium Acid	*
32 32	100 lb. K_2O 100 lb. P_2O_5 Crop Residue	No Lime	Medium Acid	—
33	Crop Residue Only	Lime	Neutral	***
34	Crop Residue Only	No Lime	Medium Acid	—

(*) Limed plots have received the equivalent of 9 tons of $CaCO_3$ since 1911.

Discussion of Data. It will be noted in Table I that the heaviest deposits of iron occur at the nodes of plants selected from limed plots, especially where the soil reaction has approached neutrality or beyond and the use of potash or manure has been left out of the treatment. Potash and manure, when applied in appreciable amounts, reduce the nodal deposition of iron very materially. The plants selected from the unfertilized plot 8, in which the soil reaction has become slightly alkaline, show a much heavier deposition of iron than those taken from the corresponding check plot 9, which shows a slightly acid reaction.

The story revealed by the data in Table II is very comparable to that of Table I. The heaviest deposits of iron occur in plants grown on the limed plots which have a neutral soil reaction and which have not been treated with manure or potash. Special attention is directed to the unfertilized plots, numbers 26 and 27. A rather marked contrast is indicated between the unlimed check plot and the corresponding check plot which received lime.

The data recorded in Table III would indicate also that lime does not render iron in the soil unavailable for plant absorption. A rather sharp contrast seems to exist between the use of lime and no lime on the check plots 33 and 34. It will be noted that a mere trace of iron was found at the nodes of plants taken from the unlimed plots.

It might appear from the discussion of these results that the contention is being made that the excessive use of lime tends to make iron more available for plant absorption. The chemical properties of iron would hardly justify that conclusion. Moreover, the addition of potash or manure in appreciable quantities seemed to reduce the deposition of iron at the nodes. That plants get iron in rather large quantities from the soil where lime has been used to excess seems quite certain. Whether or not the iron after having been absorbed by the plant is improperly assimilated and permitted to deposit at the nodes of the plant because of the action of lime in the soil is the question. It would appear that lime locks up other elements in the soil (one of which is probably potash) which are necessary for the proper iron distribution in the plant rather than rendering the iron itself unavailable for plant absorption.

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Summary. 1. Stalk tests indicate that the excessive use of calcium carbonate on soils does not render iron unavailable for corn plant absorption.

2. The application of lime increases the deposition of iron at the nodes of corn plants rather than decreases it, especially where the soil reaction had become neutral or slightly alkaline.

3. The heavy deposits of iron at the nodes of plants grown on heavily limed plots does not necessarily indicate that the total absorption of iron by the plants was greater.

4. The application of manure or potash in appreciable amounts decreases very materially the amount of iron deposited at the nodes.

5. These data indicate that lime-induced chlorosis is not a result of iron becoming locked up in the soil; but rather the result of a disturbance in the metabolism of iron after it has been absorbed by the plant.