DOES A SOIL ACIDITY TEST AS USED IN SOIL TESTING LABORATORIES DETERMINE OUR CALCIUM NEED IN OHIO SOIL?[1]

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ABSTRACT

Soil samples from many sections of the United States and Canada show a paucity of available calcium even though the pH reading seems satisfactory. Studies made on these soils show that the pH test, accurate for most purposes, does not indicate the available calcium in the presence of other fertilizer ions. A high pH does not necessarily indicate adequate calcium in the soil.

Lack of available calcium in many farm soils in Ohio is one of the biggest deterrants to profitable crop yields. Even soils of limestone origin are becoming depleted of available calcium, although the soil acidity test does not always indicate such a deficiency. The discussion in this paper is based on studies reported by W. P. Kelley (1926), Way (1850), Ganz (1905), Hissink (1922), and Gedroiz (1924). Although the problem of low yields is not universally caused by insufficient available calcium, observations and data collected since 1923 offer much evidence that our dependence on the soil acidity test has not given a true picture of the depleting lime content, not only in Ohio but in neighboring states.

The fact that many soils, exhibiting a satisfactory pH reading, were not producing profitable yields suggested the investigations from which these observations and data were taken. The accuracy of the soil acidity test is not questioned,

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but its use to determine the available calcium in the soil may be questioned. The pH reading, without a calcium test, does not give the true picture of the lime requirement of our cultivated soils. In some cases, the use of large quantities of commercial fertilizer has contributed to the confusion surrounding the interpretation of the soil acidity test. In many cases a near neutral pH was associated with a very low available calcium reading, which in most cases was corrected by the addition of finely-ground limestone.

In pursuing these investigations, it was necessary to determine as accurately as possible the calcium requirement of different soils. Pot cultures of problem soils with different crops greatly facilitated the early studies. These were followed by field tests on farms in a number of different states. It must be pointed out that there were a few cases where the addition of the required amount of limestone did not fully correct the problem. Foliage sprays of trace elements seemed to complete the picture.

Many of the soil acidity tests reported here were made by Ohio State chemists on duplicate samples sent in by farmers who were cooperating on these studies.

Most of these tests were made according to procedure described by Hestor and Shelton (1964).

DISCUSSION OF PREVIOUS RESEARCH

Tiedjens and Robbins (1931) report that a pure sand washed free of colloidal material will grow plants satisfactorily at wide variations in pH readings, providing the nutrient solution is properly fortified with calcium. If the calcium is removed, the plants will die, even though the pH of the culture is near the neutral point. In other words, there is no guarantee that, with the proper pH, there will be any growth unless considerable of that pH is due to the calcium ion. If chemically active clay is added to the sand culture, the condition found in sandy loam soils is approached. If a sodium-saturated clay is added to the sand, the roots turn brown and the plants die. The pH is satisfactory only if the calcium ion is present.

Way (1850) showed that if a basic salt was added to the soil, the calcium ion became available if it was part of the cation saturation of the soil colloid or the base exchange process; and if sufficient salt was added, most of the calcium would be made available and could be leached out, just as is done when using extracting solution to determine the calcium content in a soil sample. After all the calcium has been removed, the pH may still be near the neutral point. Thus, the pH reading of the soil may be influenced by any cation, which probably explains why there may be a neutral pH in a field soil in April and a pH of 5.8 in August. Along with this change there is a rapid decrease of ammonia in the soil from April to August. Alkaline soils have an above-neutral pH, not because of the calcium carbonate present, but because of the sodium and potassium carbonates present. Fifty tons of finely ground limestone applied to an acre foot of silt loam soil did not raise the pH above 7.3, so any pH values above 7.3 were probably due to other than calcium ions. There are no survey figures to show how common this problem may be.

Gedroiz (1924a and 1924b) and Hissink (1922) have shown that these high pH values may be encountered in humid regions, agreeing with recent observations in Ohio. Even though these soils test above neutral, the application of as much as 10 tons of limestone raised a 35-bu corn crop to more than 100 bu.

In later work, Gedroiz (1931) put a stamp of approval on the idea that both organic and mineral colloids must have more than 80 per cent of their charges saturated with calcium before a maximum yield of a crop can be expected. A very low percentage of the soils in Ohio are near the degree of calcium saturation necessary to grow the highest possible yields regardless of the amount of fertilizer applied.

Melsted (1953) is quoted as saying that calcium deficiency was noticed in corn on Illinois soils in 1948 and in 1951. This was on soil that was strongly acid. It has been my experience that either gypsum or low-grade superphosphate in mixed fertilizer, if used in any appreciable quantity, would prevent calcium deficiency on such soils, even though it might not result in maximum corn yields under such conditions. In potato-growing areas where the soils are maintained at a pH of 5.5 or lower, the large amounts of gypsum applied in superphosphate undoubtedly are responsible for preventing calcium deficiency. Today, many of our potatoes are grown on soils containing varying amounts of lime.

Tiedjens and Schermerhorn (1936) reported a situation on Sassafras and Collington sandy loam soils and greenhouse "made" soils where vegetable crops showed calcium deficiency, even though the pH values of the field soil readings were 6.4 to 7.2, and the greenhouse soil 8.6. Some of these data were collected from greenhouse soils in the Barberton, Ohio, area and from vegetable farms in southern New Jersey. I wish to thank Dr. Richard Bradfield and Dr. William Pierre for their valuable suggestions while this aspect of the work was in progress.

Soils tested were from some 500 farms located in the limestone area of west-central Ohio, from naturally acid soils in New Jersey, Illinois, Ontario, Canada, Wisconsin, Indiana, and from alkaline soils in Arizona and Texas. In all areas except Wisconsin, the majority of these soils had a neutral or near neutral pH reading during the winter and summer months with less than 100 lb of replaceable calcium. Many of these soils may have contained upwards of 100 tons of limestone per acre foot as calcium carbonate and small amounts of calcium phosphate and silicate. These soils were collected from farms where corn and small grains yielded considerably below state averages, where soybeans germinated poorly, where side dressings of anhydrous ammonia produced injury, where foliage sprays of fertilizer solution injured the leaves or produced no increase in yield, and where crops failed to respond to soil applied fertilizer.

RESULTS

Some quick tests of representative soils from different areas are given in table 1. In Samples 1–A, 1–B, and 1–C taken from the same area on an experimental farm in Marion, Ohio, considerable variation in pH readings was obtained according to the time of year the sample was taken. This is in the Brookston soil area developed in calcareous glacial till. If left fallow for several years, this soil will build up an appreciable amount of available calcium which will then support a good corn crop for one year. The addition of sufficient pulverized limestone to satisfy the calcium needs according to laboratory tests greatly stimulates corn yields on this soil. This sample is characteristic of many samples tested from Ohio.

A sample of Brookston soil, when brought into the laboratory March 1st and dried immediately, had a pH reading of 7.2. When this sample was kept moist in a moist chamber at laboratory temperature and tested a week later, the pH reading was 7.6 and the ammonia reading was very high, equivalent to 135 lb of sodium nitrate. If the soil remained moist at laboratory temperature for 30 days, the pH dropped to 6.4 and the ammonia reading was very low (quick soil test methods). The available-calcium reading was 2400 lb per acre foot. Six tons of high calcium limestone supplying 3798 lb of calcium were applied to the field, which increased the corn yield from 67 to 127 bu the first year.

Sample 2, shows a high yielding soil of the same type as shown in Sample 1 except that drainage was somewhat improved. Since the phosphoric acid and potash readings were practically the same as those in Sample 1, it seemed as though the calcium reading of 2800 lb of CaO per acre had considerable influence in maintaining the high yield, by making it possible for the crop to utilize applied fertilizer more efficiently. This soil responded to foliage sprays and dry fertilizer. Two gal of a 10–20–10 foliage spray yielded 23 bu more than where only dry fertilizer, 300 lb of 12–12–12 per acre was applied. Where foliage spray was applied in addition to the dry fertilizer, the number of bushels which could be credited to the foliage spray was only seven. The disconcerting part of this experiment was that the calcium alone increased the yield 60 bu, dry fertilizer with limestone 103 bu, foliage spray with limestone 127, and dry fertilizer with limestone and foliage spray 116 bu. The experiment raised more questions than were answered.

Sample 3, because of the negative reading on available calcium, represents an area where the application of limestone was advised before soybeans were planted. There were 400 acres involved. The grower, however, felt that if the pH was satisfactory, he was safe in planting the fields without applying the limestone. Less than one percent of the beans emerged. He blamed his loss on the dry weather, in spite of the fact that his neighbor had good stands of beans. Undoubtedly, with ample rainfall, the percentage of germination would have been appreciably better. These low-available-calcium soils are affected adversely by dry weather to a greater extent than soils containing appreciable more available calcium. Good moisture conditions seem to make more calcium available. This is a problem soil. It is a silty clay that is not well aerated. Plowing this ground when slightly wet could prevent beans from germinating. This particular spring was drier than average.

TABLE 1

Tests on soil samples collected in different areas where available calcium was deficient even though the pH of the soil seemed satisfactory*

	Location and description of samples	Organic matter (total)	pH	Pounds per acre of available	
				Calcium	Magnesium
1.	Soil of limestone origin in vicinity of Marion, Ohio. Maximum yield of corn, 60 bu				
	A. Sample taken in July	4.0	6.0	250	10
	B. Sample taken in October	4.0	6.4	400	10
	C. Sample taken in February	4.0	7.2	600	35
2.	Sample taken from farm in Delaware County, Ohio, which produced 100 bu of corn per acre.	3.0	6.4	2800	100
3.	Sample taken from farm in Hardin, County, Ohio, where soybeans failed to emerge.	3.0	7.0	None*	None*
4.	Sample taken near Mullica Hill, N. J. Collington sandy loam. Celery plants showed calcium deficiency symptoms.	1.1	6.8	None*	None*
5.	Sample from Arizona. Yellow foliage citrus trees which responded to calcium nitrate.	0.9	8.1	None*	None*
6.	Sample taken in March from non-limestone area near Ashley, Ohio, 30–35 bu of corn.	2.3	6.6	None*	None*
7.	Black loam soil from Elgin, Illinois area. Sample taken in July.	3.0	6.4	None*	None*
8.	A muck soil in northern New Jersey. Crops showed yellow foliage.	—	5.2	2400	80
9.	Loamy sand soil from Ontario, Canada. Very poor growth of all crops.	0.5	6.6	None*	None*
10.	A clay loam soil from lawn in Marion, Ohio. Poor grass.	Less than 1%	6.6	50	15

*The soil extractant was 0.3 normal sodium acetate having a pH of 4.7. The amount of calcium was not enough to register in the test which detected 25 lb or more. This test was calibrated on the basis that 40 per cent of the replaceable calcium was removed by the extracting solution. Any soil sample which gave a negative test for calcium might vary from a trace to a point where very little calcium existed in the available form.

Sample 4 is typical of sandy loam soils which are heavily fertilized with sodium nitrate in the absence of lime applications. Dr. J. S. Joffe of the New Jersey Experiment Station was responsible for finding that these soils needed heavy applications of limestone to restore their productivity. This soil had received as much as 1500 lb of nitrate of soda for a crop of celery in one year.

Sample 5 was sent to me by Dr. S. F. Wharton in 1936, while he was in horticultural work at the University of Arizona. It was taken from a citrus orchard in which the foliage was yellow-green and had a very low reading of calcium. Increasing the calcium content of the trees by the addition of soluble calcium salts restored normal green color to the foliage of the trees and increased the calcium content in the foliage from less than 2 M/eg to 1700 ppm.

Sample 6 was taken from soil in the Muskingum area where one might expect to find very little available calcium, unless lime or gypsum had been applied. In this case the pH reading, if made during the summer, probably would have been fairly indicative of the calcium and magnesium content.

Sample 7 was taken on a dairy farm near Algonquin, Illinois, where the farmer could not grow alfalfa. After applying coarsely ground limestone liberally for three years, he not only grew good alfalfa, but said his corn yields were much higher.

Sample 8 is included to show the available calcium in limed muck soil, even thought the pH reading indicated strong acidity. The calcium reading in a muck soil such as this may need to reach 6,000 lb before high yields can be grown.

Sample 9 is a very light soil from near Sarnia, Ontario, which has received barnyard manure. Crop growth on this soil was very poor. The organic matter was so highly hydrated that it came through the filter in making the laboratory test.

Sample 10 represents a sample taken from a lawn in Marion, Ohio, where Kentucky bluegrass failed to maintain itself. After applying limestone to this lawn, the bluegrass spread to fill in bare spots.

EFFECT OF CALCIUM CONTENT ON CLARITY OF SOLUTIONS

While extracting soil samples with the 0.3 N sodium acetate solution, it was found that the extracts would range from crystal clear to very dark brown. Those that were dark amber to dark brown were difficult to test for phosphorous and potash and contained no calcium and magnesium. It was found that any sample from which the extract was even a light amber color had little available calcium. Any sample which had more than 400 lb of calcium per acre was crystal clear. The application of barnyard manure to fields low in available calcium tended to intensify the color in the extract. Thus, any soil extract which had even a slight amber color was too low in available or replaceable calcium to show a test of 300 lb of available calcium per acre. These same samples, during the months of November to March, in this area showed near the neutral pH readings. There was no relationship between pH and available calcium. In spite of the fact that the limestone soils (origin in limestone rock) might contain from 75 to 150 tons of calcium carbonate per acre foot, continuous cropping apparently prevented the accumulation of sufficient available calcium to promote satisfactory crop growth. This may be characteristic of soils containing calcareous glacial till.

It is not unusual to find fields in heavily fertilized areas where a pH of 6.8 may show calcium deficiency. Horse-radish growers in New Jersey and eastern Pennyslvania preferred bone meal to superphosphate in their fertilizer mixtures. In one case in one corner of the field, horse-radish roots did not grow after being set out. They appeared to be in a sterile state. Weeds failed to grow in an adjacent corner of an asparagus field. The second year the area had spread to one half acre, and the third year the area covered an acre. In one row the roots failed to grow; in the next row, 3 ft away, the plants were a normal 3 ft tall. The pH showed no difference. When tested for available calcium, 80 lbs per acre foot were found in the good areas and 40 lb or less in the areas where the horse-radish did not grow. Two tons of limestone per acre produced good growth. Potatoes were planted in the asparagus field after it was plowed out. They made a good growth with a ton of 5–10–5 fertilizer. Here, the gypsum in the superphosphate undoubtedly prevented actual calcium deficiency.

A grower in southern New Jersey planted 40 acres of lima beans and got no germination of the seed. He brought suit against the seed company because of poor seed, even though his neighbors bought seed from the same company and had good germination. The soil and some of the same lot of seed were taken to the Experiment Station greenhouse at Rutgers. Seed planted in the soil without treatment, which showed a pH of 6.8 and a negative test for calcium, failed to germinate in the greenhouse. But when limestone, gypsum, or 16 per cent superphosphate was added liberally, 90 per cent of the seed germinated.

Truog (1953) discusses the need for higher pH values when determining lime needs for crops. To this very worthwhile statement should be added that it is very important that the pH reading truly reflect the replaceable calcium available to the crops. During the years that I have worked with farmers, 95 per cent of their problems were corrected by supplying materials that increased the available calcium for the crop concerned. Maintaining a pH for a given crop is not the problem. Rather the problem seems to be to adjust the replaceable calcium in a given soil to the point where it will best support maximum crop production. We do have different tolerances in crops. From the information available, which agrees with Gedroiz (1931) observations, apparently 85 per cent of the calcium requirement of the active colloidal matter of the soil must be saturated with calcium ions.

Some people are concerned about "over-liming injury." Many cases that were called "over-liming injury" have been corrected by the addition of more limestone. In most cases the mistake was in placing too much confidence in the pH test and not recognizing the importance of available or replaceable calcium. According to available information, if the calcium requirement of a soil is once saturated, a soil may not need additional limestone for many years depending on the type of soil.

There are many so-called "acid-soil-loving plants," which grow on soils receiving either sulphur or pulverized limestone. With the application of 50 and 100 lb of flowers of sulphur as recommended and up to 36 tons per acre of magnesium limestone, the plants grew well on limestone and died on the sulphur-supplied plots. They grew more vigorously as the limestone content was increased to the 36-ton application, though the pH reading remained at 7.2 even where limestone was heavily applied. However, it would be unwise to grow them on plots receiving more than a ton of high-calcium, hydrated lime. That is an entirely different story; it is not a pH story, but involves the balance of calcium with other basic ions.

Much criticism has been directed toward the soybean because it wears out the soil. All leguminous crops draw heavily on the available calcium supply in the soil. Yields from fields in Ohio which have grown soybeans continuously for 7 years have decreased from 37 to 7 bu an acre. A soil test on such a field would show neutral pH, but no available calcium or magnesium. One such field had three tons of magnesium limestone applied and the yield was increased to 29 bu an acre the first year with no other fertilizer added. The composition of plants as given in most textbooks is probably only a fair estimate of what one might find in any given area. Where calcium exists at optimum levels, crops undoubtedly remove proportionately more calcium and magnesium than under sub-optimum conditions. Continuous cropping, which removes available calcium more rapidly than it can be replaced, prevents crop yields from reaching maximum levels. If this is the case, then we have many acres where the soil test shows a satisfactory pH reading accompanying a critically low reading of calcium and magnesium.

In addition, a pH test does not differentiate between the lime needs of different soils. Much more limestone is needed in an acre foot of clay loam than in sandy loam soil, because there are more chemically active colloids in the heavy soils. Thus, to do a good job of liming a soil, the amount of chemically active organic matter and colloidal clay present must be determined in order to know how to figure the base exchange capacity of the soil. Then the number of pounds of available calcium needed by the soil can be figured, not only to shove the pH up from 5 to 6 to 7, but to get the maximum yield for a given set of weather conditions. This figure can range from one ton of limestone in a loamy sand to 40 tons on a muck soil. For example, by doing nothing more than applying 40 tons of pulverized limestone to a muck soil, a 40-bu corn crop was changed to 275 bu. Greenhouse growers have changed rose yields from 20,000 to 100,000 flowers in a given period by putting on 7 tons of limestone an acre on six-inch benches. On an experimental plot on a farm in Illinois, a 20-ton application of limestone has been shown to be definitely better than 15, 10 or 5 tons.

We have depended on the soil acidity test to keep our soils adequately supplied with calcium, so we have short-changed ourselves to the present situation where our lime needs in Ohio are stupendous. Many farmers are losing their farms because they depended on the soil acidity test. Our soil acidity test is not a satisfactory test for determining the calcium and magnesium needs for optimum growth of crops.

LITERATURE CITED

Ganz, R. 1905. Zeolithe und Ahnliche Verbindungenihre Konstitution und Bedeutung für Technik und Landwirtschaft in Jahr. Preus. Landesanst Bergakad. 26: 179–211.

Gedroiz, K. K. 1924a. Soils unsaturated with bases. Method for determining—in soils—the hydrogen present in an absorbed condition. Soil requirements of lime as a neutralizing agent. In Zhur. Opit. Agron. 22: 3–27.

———. 1924b. Ultramechanical composition of soils and its dependence on the nature of cations present in the soil in an absorbed condition. Liming as a means of improving the ultramechanical compositions of the soil. In Zhur. Opit. Agron. 22: 29–50.

———. 1931. Exchangeable cations of the soil and the plant. 1. Relation of plant to certain cations fully saturating the soil exchange capacity. Soil Sci. 32: 51–63.

Hestor, J. B. and **Florence Shelton.** 1964. Know your plant and soil requirement. Research monograph 3, Dept. Agric. Research, Campbell Soup Co., Riverton, N. Jersey.

Hissink, D. J. 1922. Bitrag zur Kenntnis der Adsorptionvorgange im Boden. Method zur bestimmung der Austauschfahigen odor absorption gebimdenen basen im Boden und die Bedeutung dieser Basen für die Prozesse, Mitt. Bodenk. 12: 81–172.

Kelley, W. P. 1926. A general discussion of base exchange in soils. J. Am. Soc. Agron. 18: 450–458.

Mattson, Sante. 1926. The relation between the electro-kinetic behavior and the base exchange capacity of soil colloids. Am. Soc. Agron. 18: 458–470.

Melsted, S. W. 1953. Calcium deficiency in Illinois. Better Crops Magazine (February). Am. Potash Inst. Inc. Wash. 6, D. C. 30: 31.

Tiedjens, V. A., and **W. R. Robbins.** 1931. The use of ammonia and nitrate nitrogen by certain crop plants. N. J. Agr. Exp. Sta. Bull. 526.

———, ———, and **L. G. Schermerhorn.** 1936. Available calcium a factor in salt balance for vegetable crops. Soil Sci. 42: 419–433.

Truog, E. 1916. The cause and nature of soil acidity with special regard to colloids and adsorption. J. Phys. Chem. 20: 457–484.

———. 1953. Lime and pH. Country Gentleman Farm Magazine. Curtis Publishing Company.

Way, T. J. 1850. On the power of soils to absorb manures. J. Royal Agr. Soc. England. 11: 313–379.