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We Can Grow Legumes on Acid Soils

Alfalfa and clovers fail not because a soil is sour but because the fertility has leached away. Liming alone will not cure a sick soil. In fact, overliming may do more harm than good. Our soils need a well balanced supply of all plant food elements to remain productive.

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LEGUMES are almost an indispensable forage for the dairyman. They are high producers of his raw proteins, or the amino acids from which his cows produce the milk proteins. Legumes can use, both from the soil humus and from the atmosphere, the nitrogen that characterizes the chemical composition of these life-carrying substances. But unfortunately legumes are feed crops not grown so universally. We have ascribed their failure to the acidity of the soil. Whether this diagnosis of the trouble is correct may be questioned. It deserves reconsideration in the light of our better understanding of the soil and its interactions with the plants.

Soil Acidity is a Deficiency of Fertility

Acidity is a common soil condition in many parts of the temperate zone. It occurs where the rainfall gives water enough to go down through and to wash out much of the fertility. In general, if the rainfall is high enough to provide plenty of water during the crop-growing season, there will also be enough water to leach the soil of much of its supply of nutrients and to make it acid.

Timbered soils of the eastern United States are acid. Those of the eastern edge of the prairie are also sour. Acidity is a natural condition where soils have had rainfall going down through them and where they have been growing much vegetation. Such soils have, therefore, been subjected to a leaching force taking the fertility downward, and to a competitive force of the vegetation with its roots taking the nutrients upward. There they are built into organic combinations of them. Consequently acid soils have a distinct surface soil and subsoil horizons in their profiles. They are naturally low in fertility and have been growing mainly carbonaceous or woody vegetation.

Natural soil acidity is in reality, then, mainly a shortage of fertility in terms of many plant nutrients. This is the situation because the soil has been under cropping and leaching for ages. This was true before we took over to intensify these effects. This, then, is the condition of the soil that prompts the common question. How can we grow mineral-rich, fertility-consuming forages, like the legumes, of good feed values for such a high-powered, protein-producer like the dairy cow?

Liming the Soil is an Old Agricultural Art

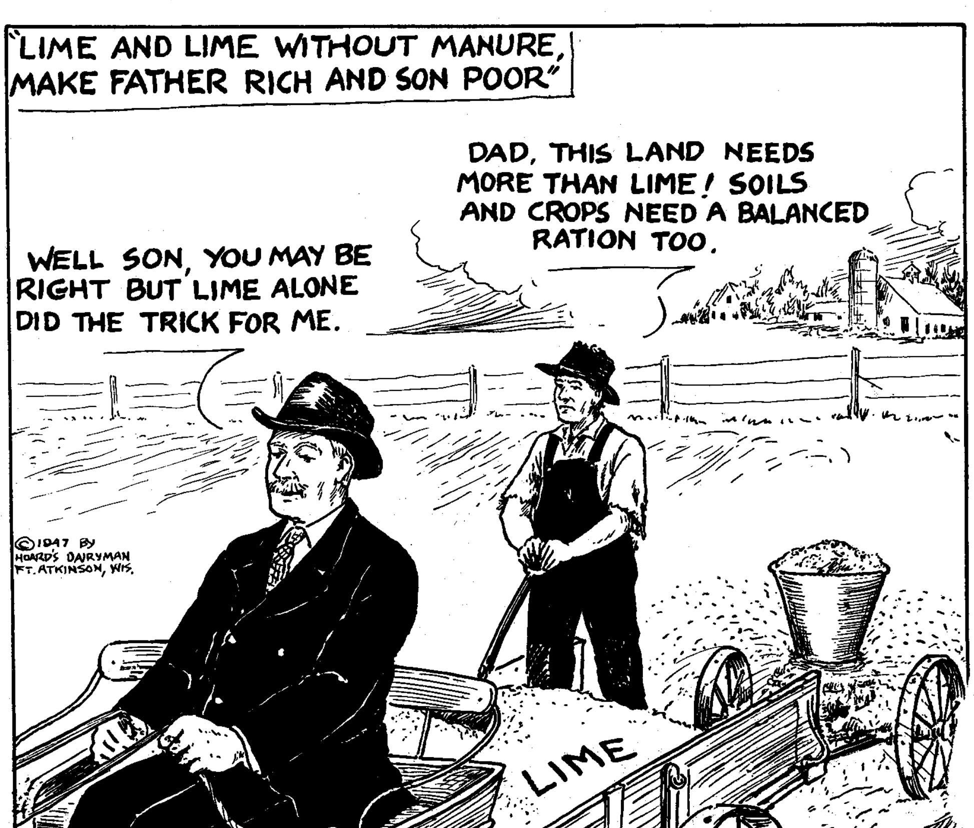
Applications of limestone, and other compounds carrying the nutrient calcium, to acid soils are known widely to be beneficial soil treatments for legumes and other crops. This was known even to the Romans who used lime as a fertilizer on their soils. Much later in general, but yet early in our own colonial history, it was reported that Benjamin Franklin used gypsum or land plaster on clover with good improvement of this legume crop. Here right on our own soils the ancient agricultural art of liming the land was practiced for the benefit of better crops as feed. Here the sulfate of lime, or gypsum, which does not take away the acidity of the soil was making better clover. We have forgotten this unusual wisdom about soils among the many bright ideas that came down to us from this colonial sage. We may well go back and look carefully and critically into it now. We need to ask ourselves, "Why can't we grow legumes on acid soils when Franklin grew them better by putting on calcium sulfate?" This was a soil treatment that not only failed to reduce the soil acidity but even made the soil more sour.

A Little Science Led Us Astray

It was the growing agricultural science of the early decades of the twentieth century that brought liming of the soil back as a more general agricultural practice. We cannot say that liming was an art carried over from colonial days. It had been pushed out when fertilizers came into use. Liming the soil has become an extensive practice under the encouragement of an embryo soil-testing service. That service was guided by the belief that the applications, (a) of limestone which is a carbonate of calcium, (b) of hydrated lime which is an alkaline calcium hydroxide, or (c) of quicklime, caustic oxide of calcium, are all beneficial for crop growth because each of these is ammunition in the fight against soil acidity, or against the high concentration of hydrogen in the soil.

This struggle to drive the hydrogen ion, or acidity, out of the soil was aided by the technological advancements giving us instruments and equipments that measured the hydrogen ion to a finer degree than known before. The ease and speed with which soil acidity could be detected and measured encouraged the widespread testing of soils. This activity discovered soil acidity almost everywhere. Through the help of the measuring gadgets we were impressed by the apparent universality of soil acidity. Only a few humid soils were not seriously stocked with acid. We discovered that for acid soils, in general, the productivity was lower as the degree of acidity was higher. From such a discovery we might expect ourselves to conclude — even though it was later found to be the wrong conclusion — that the presence of the large amount of hydrogen ions in the soil was the cause of the poor crops. This conclusion would be expected also from the bigger troubles in growing the proteinaceous, mineral-rich legumes of higher feeding values.

The extensive use of limestone in the corn belt has now multiplied itself into the millions of tons of these natural rock fragments that are annually mixed through the soil. This increased use was prompted by the beliefs (a) that limestone is beneficial because its carbonate removes the acidity of the soil, and (b) that soil is most productive if it is neutral, or when it has no active hydrogen ions in it. Under these beliefs (now known to be poorly founded) we have become belligerent foes of soil acidity. Limestone has become the ammunition for fighting this enemy hidden in the soil. Under national financial aid we have been prone to believe that in putting limestone on the soil we can follow the old adage which says "If a little is good, more will be better." We are just now coming around to a better understanding of how Nature grew crops on the acid soils before we did. We are now beginning to understand what limestone really does when it makes better crops.



More Science Shows Limestone Feeds Crops While It Fights Soil Acidity

Only recently have we recognized the fallacious reasoning behind the conclusion that it must be the presence of the acidity in the soil that brings the crop failure when liming lessens the soil acidity and makes better crops at the same time. While the convenience of soil testing gadgets encouraged this erroneous belief about soil acidity as an enemy, it was the diligent study of the physiology of the plants, of the colloidal behavior of the clays growing them, and the chemical analyses of all these, that finally pointed out the errors of such hasty conclusions. It pointed out that soil acidity is not detrimental, but is in reality beneficial.

We now know, of course, that in applying the limestone, which is calcium carbonate, there is possibly some reduction of acidity by the carbonate portion. At the same time there is being applied also some calcium—a nutrient highly deficient in the leached soils—to nourish the calcium-starved crops. This nutritional service comes about both directly and indirectly. We have finally learned that it is this better nourishment of the crop rather than any change in the degree of acidity of the soil that gives us the bigger and better crops. Unwittingly we have been fertilizing the crops with calcium while fighting the soil acidity with the carbonate, the hydroxide, or the oxide of lime.

In spite of our ignorance of how the lime functions, we have benefited by using it. However, an erroneous understanding of what happens to the crop and to the soil when we lime cannot successfully lead us very far into the future. We cannot continue to grow better feeds under the mistaken belief that we do so merely by the removal of the soil acidity through the use of plenty of carbonates on our humid soils. Wise management of the soil to grow nutritious feeds can scarcely be well founded on facts so few and so simple.

Simple Tests Demonstrate Lime Beneficial Through Calcium

Should you decide to demonstrate for yourself the truth of what has been said above, you can apply some soda-lime, or sodium carbonate to the acid soil. This will reduce its acidity. But unfortunately for you if you are a foe of soil acidity, this soil treatment will rout the enemy but will still not give successful crops. Merely removing the acidity by a carbonate (of sodium rather than of calcium, in this case) does not guarantee the crop.

As proof that it is the calcium as plant nourishment that is the helpful factor in liming, one can repeat Benjamin Franklin's demonstration and apply calcium sulfate to the soil. One might even apply some "Dow Flake," a calcium chloride. Either of these calcium-carrying compounds will make the soil more acid. But in spite of this fact and because they add calcium, the gypsum and "Dow Flake" will improve the crops on the initially acid soil left so. We are now resurrecting the ancient art used by Benjamin Franklin for whom liming the soil was a matter of fertilizing it with calcium (and sulfur) and not one of fighting soil acidity.

Neutral Soils Are Not Necessarily Productive

While we were fighting soil acidity we have failed to notice that most of the populations of the world are concentrated on the acid soils. They are not in the humid tropics where the soils are not acid. Nor are they on the arid soils that are alkaline, a reaction opposite to the acid. Soils that are not acid are not necessarily the supporters of many peoples. Yet in fighting soil acidity we labor under the belief that if a soil were limed to the point of driving out all the acidity, such a soil should be highly productive.

We now know that even while a soil may be holding considerable acidity or hydrogen, it is also holding considerable calcium or lime. To a small extent of its exchange capacity, it is also holding nutrients other than calcium. Among these are potassium, magnesium, manganese, and others. But these in total are held in much less quantity and by less force than are either the calcium or the hydrogen, the former a nutrient and the latter a non-nutrient. Should we put on lime or calcium enough to drive all the acidity out of the soil by putting calcium in place of the hydrogen, all the other nutrients would be more readily driven out than would this acid-giving element.

Liming the soil heavily, then, does not necessarily drive out only the acidity. Instead it would also drive out all other fertility. It might load the soil with calcium so completely that it could offer only calcium as plant nourishment. Plants would then starve for other nutrients even though on a neutral soil. Plants on such a non-acid but calcium-saturated soil would be starving for all the same nutrients, except calcium, as they do on the acid soils. Making soils neutral by saturating them with calcium does not therefore make them productive. This is the situation of some of the semi-arid soils of our western states. In our struggle against soil acidity we need to remember that neutral soils are not the productive soils. Instead it is the acid but yet fertile ones that feed us and nourish the major portion of the other peoples of the world.

Acid Soils May Need More Than Lime

Calcium has been a good fertilizer for legumes on acid soils now for some years. It has been serving directly as a nutrient for the plants. But it has also served indirectly by helping other nutrients get into the plant roots more abundantly. It helps the nitrogen of the acid soil to get into the plant. It helps the phosphorus, the potassium, and other nourishing elements

Better crops and less plant disease result from more calcium delivered as more of the acid clay (pH 4.4) was mixed into the sand (left to right). Photo by Missouri Agricultural Experiment Station.

to be taken more readily by the crop. A plant grown for a short time on a lime-rich soil and transplanted to one low in calcium—that is, one that is acid—will take more nutrients from such a soil than will the plant that was starved in its early life for lime. It is because of this behavior of the calcium that a limed soil is soon in need of other nutrients beside the calcium.

We are discovering rapidly that there is need now for potassium on many recently limed but still acid soils. Other soils in similar condition show their serious needs for nitrogen. Lime, of course, may well be the first fertilizer needed. But when once this need is met on these soils that were highly leached long ago, the need for other nutrients may be quickly evident. Perhaps it is these fundamental soil facts that are bringing fertilizers into such prominence in the corn belt today, while only a few years ago limestone was the only soil treatment and the one starting then its extension into the widespread use it has today. Perhaps these are the facts behind the age-old rhyme that told us long ago that "lime and lime without manure, make father rich but son poor."

Better Nourishment

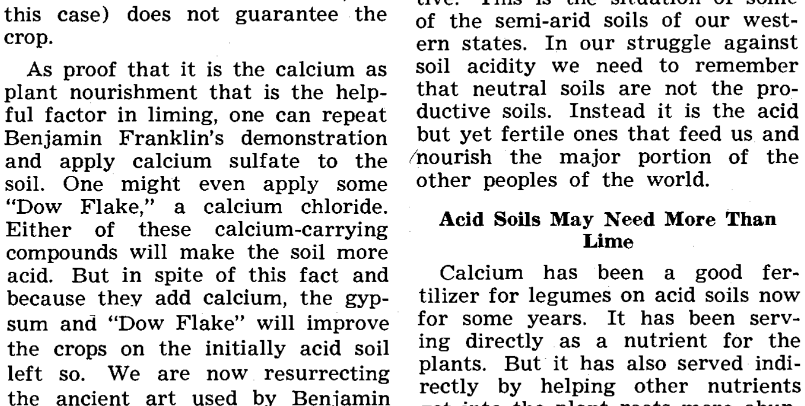
We now know that instead of saying that acidity has come into our soils we should say the soil fertility has gone out. Legumes which make good feed for milk producing animals must have fertile but yet acid soils from which to make the feed that will be good. Lime is one of the foremost fertilizers in making soils capable of supporting the protein producing crops. For this service to plants, phosphorus is also needed. Then, too, a plant needs potassium to make the carbohydrates from which the proteins can be constructed through the help of these soil-borne nutrients. Not only one element but many nutrient elements are needed. These are taken out of the soil as the plant trades hydrogen as acid for them. Consequently the highly acid soil is simply one that has become deficient in fertility.

We can grow legume crops on acid soils if we will give them calcium and all the other fertilizers needed by the soil to grow them. Red clover was commonly said to be sensitive to acid soils. Yet liming the millions of acres has not restored this crop to those extensive areas. The high cost of its seed is sufficient testimony of the crop's scarcity today. This crop usually needs potassium, or phosphorus, or possibly other fertility elements on a soil deficient to the point of being naturally very acid. Then, too, when a soil is properly fertilized, red clover will grow even if the soil is highly acid. We now know that the soil acidity is not the problem in growing the legumes. The production of these protein producing crops is a matter of ample soil fertility among which the calcium is only one nutrient. If we provide this one by means of limestone and then add all the other necessary fertilizer nutrients for the soil in question, we can grow legumes of highly nutritious values as feed without removing all of the soil acidity. Growing legumes is a matter of feeding these crops, and not a matter of fighting soil acidity.

Soybeans came in as a "new" legume crop. They were reported to "grow on acid soils." But on such soils they were also reported to be "a hay crop and not a seed crop." We did not realize that if they were not building proteins and other complexes demanding soil fertility to make a seed crop and that consequently they could not be a nutritious hay in these respects. Soybeans need lime, too, if they are to give good feed. They are showing growth troubles when the soils are not well supplied with magnesium. They are also reporting the need for manganese on some soils. Soybeans can be grown on an acid soil that is fertile in more respects than in calcium only.

We need no longer hunt for "acid-tolerant" legumes. Any plant that is well nourished tolerates acidity. It causes the soil to become acid when it takes the fertility from it. The root itself is acid and makes the surrounding soil area acid by the carbonic acid it respires. It is this carbonic acid by which the plant carries on the business of taking calcium, potassium, magnesium, phosphorus, iron, and its whole array of nutrients from the soil. It trades hydrogen or acid for them. Acidity is therefore "natural" for any plant.

Growing legumes is not a problem of getting rid of the acidity of the soil. On the soils where we say acidity is a problem, the problem is one of putting in place of the acidity the list of plant nutrients lost excessively from the soil as it became acid. Legumes that make tons of vegetative mass on so-called "acid" soils do not make the nutrient values or quality of feeds made by those other legumes we say are "failing" on acid soils. We can grow some legumes on naturally acid soils but they will not be the equal in feed value of those on soils once naturally acid soils but given other fertility as well as some calcium in the belief that it was removing acidity. Good feed can be grown on acid soils provided that they are given the fertility required by the plant to manufacture it. Soil acidity is a problem because it means that so much fertility has gone out to let so much hydrogen come in.



Red clover grows on an acid soil provided the soil is fertile with respect to other nutrients as well as calcium. Manure with little lime has long been a good fertilizer for red clover which grows on acid but fertile soils.

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