

# **AGRICULTURAL LIMESTONE**

## **For the Sake of More than Its Calcium**

**By WILLIAM A. ALBRECHT**

Department of Soils, College of Agriculture  
University of Missouri

# ***pit and quarry***



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# AGRICULTURAL LIMESTONE

## For the Sake of More than Its Calcium



THE use of limestone on the soil is an agricultural practice as old as the Romans and the centuries B.C. But the concept of how and why its application on humid soils can modify them enough to grow better legumes and other crops of higher protein contents and nutritional values, is still recent and incomplete. A more adequate understanding of how calcium carbonate, *i.e.*, limestone, a calcium salt of carbonic acid, functions in growing better crops is still challenging the research thinking of students in soil fertility and plant nutrition.

Liming the soil has long been a wise practice — but for the wrong reasons. It has long been the belief that this cheaper carbonate serves because this part of the compound overcomes the condition called “soil acidity” by neutralizing or removing the soil acid, *i.e.*, hydrogen. This explanation, though not in accord with the natural facts, has persisted since the time of Edmund Ruffin (1794-1865), a Virginia farmer, who was probably the first one to call attention to what is commonly considered “soil acidity” in upland, mineral soils of the humid climates.

The belief that soil acidity is bad for plants because of the presence in the soil of ionic and therefore highly active hydrogen was reinforced and widely disseminated as a result of the demonstrations by H. J. Wheeler (1861-1945) of Rhode Island, who showed that many upland soils are distinctly acid in chemical reaction and will grow better crops when limed. This was the beginning of the wise practice of using limestone as a fertilizer to build up the sustaining mineral fertility of the soil. It was also the beginning of the propagandization of the erroneous explanations of how it functions, when it was claimed that limestone serves because it reduces the degree of, or removes completely, the acidity or active, ionic hydrogen of the soil.

The persistence for almost a century of this erroneous explanation illustrates our reluctance to study the facts of Nature. It illustrates, also, our readiness to accept without scrutiny what some one reports as

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Department of Soils, College of Agriculture  
University of Missouri

truth. The failure to see so-called “acid soils” as a case of *fertility deficiency in terms of calcium and magnesium*, while making acid the scapegoat and fighting it by applying the carbonate part of the limestone as ammunition, has its modern parallel. We made the microbe the scapegoat in disease, rather than seeing the invasion of the body by almost any micro-organism as the symptom of nutritional deficiencies, and maintaining our body’s own protection against them. Such is the slow rate at which we come to understand Nature’s mysteries, Her causes and Her effects.

In both the arts of managing agriculture and of maintaining health, there is still much that is empiricism, or mere practice to get results, regardless of our unfamiliarity with the natural laws underlying agriculture and health. Yet in an age of science, while making an effort to organize our knowledge and to comprehend causes and effects, we dare not propose to work with Nature in food production of high nutritional value unless we learn how and why the natural processes function through the soils and crops in that activity.

Colloid chemistry interpreted soil acidity as fertility deficiencies. We learned lately that limestone func-

tions, not because its carbonate part neutralizes or removes the acidity or hydrogen from the soil, but rather because it fertilizes the soil with calcium and magnesium. This concept came to us when colloid chemistry became a part of the larger science of chemistry. By the help from that segment of this science, the clay of the soil was recognized as a silicate colloid with many negative electrical charges. It was found to be performing according to its enormous surface for adsorbing and exchanging the many positively charged atoms, or ions, like hydrogen, calcium, magnesium, copper, zinc, and the host of others, including both the essential and the non-essential for the nutrition of plants and animals.

By experimenting with clay in accordance with the natural laws outlined by colloid chemistry, *i.e.*, by adsorbing on clay varied amounts of both calcium and hydrogen in which plants were grown, differences in plant growth served to separate the effects of the calcium on the clay from the effects of the hydrogen held there. Since both calcium and hydrogen, the former a nutrient and the latter a non-nutrient, are positively charged and held by the clay, they were experimentally put there as increasing concentrations of calcium associated with reciprocally decreasing concentrations of hydrogen or acidity, in one plant series. (See illustration, upper series.)

In another plant series the same concentrations of calcium were used, but associated with decreasing concentrations of potassium, thus excluding nearly all the hydrogen, or all the acidity. (See illustration, middle series.)

Likewise, in place of hydrogen, positive elements, or cations, like magnesium, barium, and even the organic molecule methylene blue (illustration, lower series) were reciprocally associated with the varied concentrations of calcium, each in other plant series. None of the soils were acid in these other-than-hydrogen series. Yet the increases in the growth of the plants in each series followed increasing concentrations of calcium supplied on the clay in the sand-clay soil. The plant behaviors on these nearly neutral soils duplicated the growths of the series in which the increasing concentrations



William A. Albrecht

of calcium in association with decreasing hydrogen concentrations represented decreasing degrees of soil acidity. This occurred when the amount of total exchangeable calcium in the many sand-clay soils was kept constant.

This experimental work demonstrated clearly that deficiency of calcium as a plant nutrient was the trouble with the so-called "acid" clay, rather than the presence there of hydrogen, since the nearly neutral soils duplicated the plant growth given by soils of decreasing acidity and reciprocally increasing calcium saturation. Thus, regardless of whether the soil acidity in the plant series was lowered by the successive units, or whether all the soils were almost entirely neutral and all of the same degree of soil acidity, plant growth responded to concentrations of exchangeable calcium on the clay and not to concentrations of hydrogen, or the degree of acidity (pH) present.

As a consequence of these demonstrations of plant behavior, the practice of liming soil is now viewed as an attempt to put the nutrient elements calcium and magnesium on the colloidal clay part of the soil in their proper ratios to each other and in proper ratios to all other positively charged atoms, or ions, held by the clay for exchange to the plant root as nutrition. Liming is no longer a fight on acidity, or hydrogen, in the soil. In fact, calcium and magnesium move into the plant more efficiently if there is some hydrogen present on the clay, and is present even in certain ratios to calcium, magnesium, and to other nutrient ions of positive electrical charge.

Liming the soil is mainly an application of fertilizing materials. It is not a case of using a *starter fertilizer*, but one of building up the *sustaining fertility* for many years to come. When for better growth of plants, calcium is put on the clay to take as much as 75 percent of its adsorbing capacities, when magnesium is put there to represent about 7.5 percent, and when the potassium supply there amounts to about 3 percent, these three nutrient ions, comprising about 85 percent of the clay's capacity, will leave little chance for much hydrogen ion, or acidity, of similar positive charge on the clay.

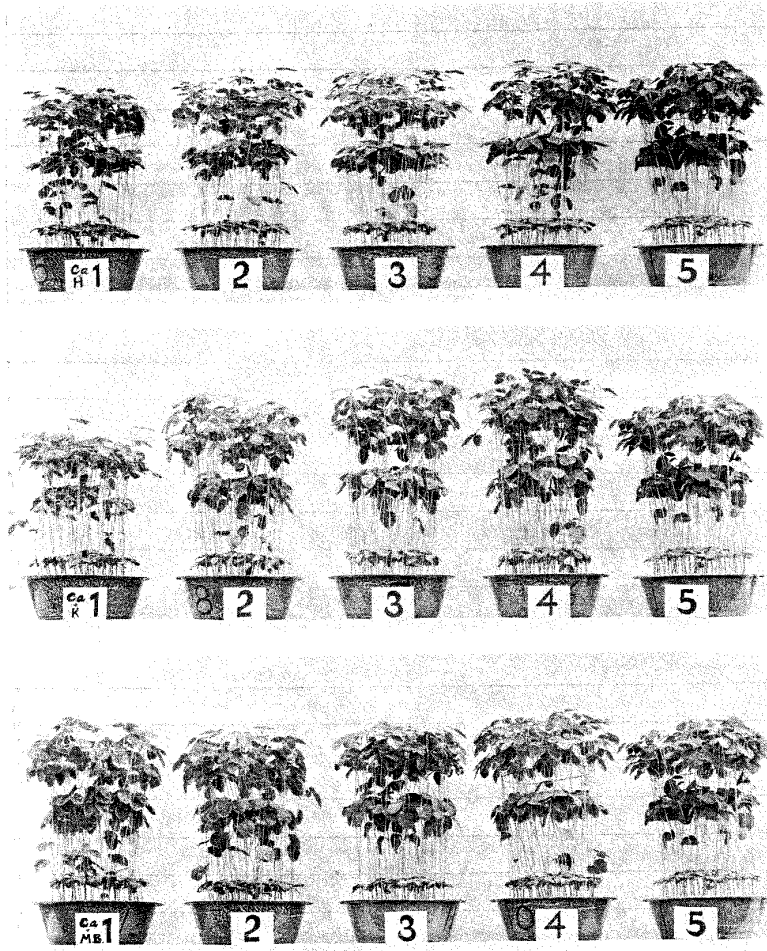
Consequently, liming soil is a practice of loading the clay so highly with fertility elements that the partial removal of hydrogen (or its partial displacement from the clay by those elements) is merely a reciprocal re-

sult. When the entrance on to the clay of the fertility, and not the exit therefrom of the acidity, is the major cause of improvement in the crop growth, we may well direct some attention to the possible need for some hydrogen to be always present in the soil. The presence of hydrogen on the soil naturally has always been the case for humid soils. There we have regularly had maximum plant production in the presence of soil acidity. Let us consider the possible benefits from some hydrogen in the soil. Experimental studies suggest that hydrogen, a non-nutrient cation, serves beneficially for activation of nutrient cations when hydrogen occupies about 10 percent of the clay's capacity; calcium, 75 percent; magnesium, 7.5 percent; and potassium, 3 percent. Accordingly, any single one of the cations adsorbed on the clay seems to behave according to

the company it keeps, whether that be nutrient or nonnutrient, including even hydrogen, which was so long erroneously considered injurious.

Shall we lime for the sake of carbonic acid as well as for calcium? When the application of lime as calcium carbonate loads the clay with calcium, it also is replacing hydrogen from there to unite with the carbonate part of limestone, and liming soil is likewise a case of treating carbonate with an acid soil and thereby producing carbonic acid in the soil. Let us give some consideration, then, to the possible significance of the carbonate part of limestone, or carbonic acid resulting from liming as an active factor in bettering soil for plant growth, since now we know that acidity makes many ions more active for entrance into the plant roots. Dare we emphasize only the

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Less clay, more highly saturated by calcium (left to right), but of such amounts of clay in the sand to supply constant totals of exchangeable calcium per crop, show better growth (left to right, upper series) where acidity decreases accordingly, and likewise where there is no acidity (middle series).

Where varied calcium saturation is associated with the organic compound methylene blue on the clay, the crops do not vary with calcium saturation but are uniform with the constant total exchangeable calcium in the soil (lower series).

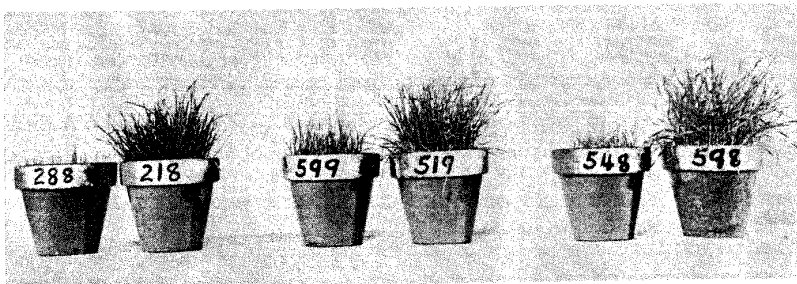
## Agricultural Limestone

smaller, active cations of positive charge like hydrogen, calcium, magnesium, potassium, sodium, etc., held on the large, sluggish clay anion of negative charge, and disregard other anions like bicarbonate, nitrate, chloride, sulphur, phosphate and even all the organic anions, as well as these inorganic ones?

Now that we have emphasized these cations on the clay because they replace hydrogen (or because they are what we thought of as "bases" for neutralizing acid), we have forgotten that either calcium or magnesium in limestone is speedily effective and safe in large doses only when it is applied as a carbonate. Calcium reacts differently when put on soil as sulphate, in gypsum, or in phosphates. Since soil liming as an ancient art brought our thinking of it slowly around to become scientific about its services in applying calcium, and thereby helped us to appreciate the services from other cations, we may well inquire about the services of liming for its application of the carbonate anion; we may likewise consider the services from anions other than carbonate, as used in other fertilizers.

In virgin soils the negatively charged bicarbonate anion is the most universal one by which positively charged cations in rock minerals are broken out to become active. Carbonic acid is Nature's most universal acid and mineral-dissolving reagent. It puts most of the cations into active form. Resulting as it does within the moisture around the microbe or the plant root into which the waste carbon dioxide is respired by these life forms, they are regularly enshrouded, then, with active hydrogen in company with the carbonate anion. This hydrogen can then be exchanged by the root or the microbe to the clay surrounding it, from which it takes ionic active nutrients like potassium, calcium, magnesium, and others.

It is by this continued exchange of hydrogen from root to clay and by crop removal of the nutrients taken from the clay that soils become acid naturally. The acid soil then in turn decomposes the rock reserve minerals, among them limestone. Thus, since carbonic acid is the great reagent for processing the original rock substances by which growth of crops can take place, we can see the good in the carbonate part of limestone when we lime the soil, and soil acidity serves to process this stone to give carbonic acid as well as to stock the



Fresh organic matter added to the soil ahead of the grass seedlings stimulated better early growth as pot tests demonstrated for orchard grass, timothy, and brome grass (left to right, by pairs).

288—rye soil, rye under—plus chopped Irish potatoes

218—rye soil, rye under—plus green turnips and tops

599—rye grass soil, rye grass under—plus chopped oranges

519—rye soil, rye under—plus chopped green turnips and tops

548—alfalfa soil, alfalfa under—plus chopped Irish potatoes

598—rye grass soil, rye grass under—plus chopped oranges

(Courtesy of Chas. J. Schnabel)

clay with calcium and magnesium.

One needs only to recall that neither calcium sulphate, *i.e.*, gypsum, nor calcium chloride, *i.e.*, Dow-flake, can be used on the soil in equal amounts with the same degree of safety as calcium carbonate. If the proper ratios of nutrient cations—calcium, magnesium, potassium—and the non-nutrient hydrogen held by the clay are a significant matter for better plant nutrition, it seems logical to raise the question for research whether the less adsorbed anions, nutrients like nitrate, chloride, sulphate, and phosphate, or supposed non-nutrients like bicarbonate, for example, must not also be present in proper ratios as the mates of cations, if their combined interactions and effects are to result in proper plant nutrition and crop production.

Liming the soil, as it supplies carbonate and liberates carbonic acid, Nature's most universal anion, would suggest that we have been more fortunate in our use of limestone as a form of "sustaining fertility" than we yet appreciate. Perhaps Nature has been caring for us in spite of our ignorance of these natural performances, rather than because of our knowledge of them.

**Limestone helps put more organic matter into soil.** While carbonic acid given off by limestone in acid soils may be considered an inorganic acid, its carbon is nevertheless of organic origin. This acid behaves like other organic acids in that it does not give highly active acidity. We appreciate this fact when we taste acetic acid, an organic acid, in vinegar.

Carbonic acid has neither a highly stable nor a highly soluble acidity, as we learn by drinking carbonated waters. It does not activate its hydrogen completely, and therefore it

has much of its total content inactive or un-ionized. It decomposes, producing carbonic dioxide, which escapes into the atmosphere. It also produces water, which when left in the soil, shows no acidity. This is quite different from what happens when calcium chloride is put into soil. That compound is calcium salt of muriatic or hydrochloric acid. It is highly active, does not decompose readily, and is highly soluble.

There may be more good fortune for crop nutrition than we appreciate in the fact that calcium, magnesium, and potassium, which compose most of the nutrient cation supply on the clay, take to the bicarbonate forms of compounds so readily. Were they in the soil only as chlorides, rather than the bicarbonates, it is certain that in such large supplies they might be injurious to plant nutrition. Heavy applications of muriate, *i.e.*, chloride of potassium as fertilizer are reported to show these disturbing results. Damage is most serious on soils which are low in organic matter, and therefore where there is less carbonic acid from organic decay, which would produce carbonic acid in larger and regular quantities to offset the detrimental effects of chlorides and other anions. Chloride in small quantities (much like trace elements) is a necessity for plant nutrition, but in large amounts it seems a more serious disturber than is commonly appreciated.

While we believe calcium to be more effective in the presence of organic matter and carbonic acid, we need to remind ourselves that, reciprocally, organic matter has built itself up to higher concentrations throughout greater depths of the soil where the supply of calcium has been high. It is calcium that helps grow leguminous crops; and the nitrogen

of legumes, taken from the atmosphere, holds carbon. We also know that, when they are applied on soils of high organic matter contents, can the concentrated salts in fertilizers be used with least disturbance from the "salting effects" which the chloride of calcium, for example, exhibits so highly in contrast to the carbonate compound of that element.

It is interesting that the amounts of highly concentrated fertilizers used have increased recently only in that area of the United States where soils are still high in organic matter. The amounts used have decreased on soil of low organic matter. The organic part of the soil has been the "shock absorber" for the "salt" danger from chlorides, nitrates, and sulphates of sodium, ammonium, and potassium, or those combinations of more active, monovalent elements commonly used in fertilizers.

These facts present the question whether carbonic acid serves to lower the activity of and thereby lessen the possible injury from these cations, *i.e.*, sodium, ammonium, and potassium, by combining with them, and also to lessen the injurious activities of the anions, *i.e.*, chlorides, nitrates and sulphates, by diluting them with itself, a less active anion. Perhaps such theoretical thinking should be considered, since liming is effective on those soils lower in organic matter and is required there to enhance the efficiency of many other fertilizers, with resulting nutritional effects we cannot yet comprehend, much less explain.

On Sanborn Field at the Missouri Experiment Station, one plot has been in continuous wheat cropping under a heavy fertilizer treatment which applied the equivalent of nitrogen, phosphorus, and potassium removed in the grain and straw of a 40-bushel crop since 1888. This heavy application of salts with the seeding was without injurious effects for about 30 years. But during the last 35 years, or since the organic matter has been seriously lowered through such treatment and has not been built up by the return of any crop residues, it has been necessary to divide this heavy fertilizer treatment into two and more applications to escape injury to the seeding from these applied salts.

Before commercial nitrogen fertilizers were so extensively available, we were building organic matter and nitrogen into the soil by growing protein-rich and mineral-rich legume crops. Unfortunately for the rebuilding of the soil's supply of organic matter, legume crops were such good

and seriously-needed feeds, that they did not find their way into the soil to build up much organic matter there. Now that commercial nitrogen is going into non-leguminous crops, which do not require soils highly stocked with calcium, it is believed that nitrogen is building proteins by pushing higher the nitrogen content of grasses and producing the equivalent of legumes grown by liming and fertilizing for them.

In this belief we forget that in measuring the total nitrogen in the crop and in multiplying this value by 6.25 to call the result "protein", we are not measuring proteins complete enough in their required constituent amino acids for nutrition of our animals. We are getting a value of "crude" proteins; that includes other forms of nitrogen than those in the amino form of the protein. Those others include nitrogen in the organic-ring combinations, in ammonia, and even in nitrates.

The drought of 1954 put enough of this form of nitrate into corn stalks to be over half the total nitrogen commonly contained in them. This form of nitrogen was concentrated highly enough to kill livestock that consumed the fodder. This experience serves to tell us that grasses, like corn, grown readily without attention to soil liming, even if they have high nitrogen (and thereby high "crude" protein) contents, are not giving us the feed values we get when we lime the soil and grow legumes for feed. Quality knows no substitutes.

We should recall that the soils well stocked with organic matter (because they were also well stocked with lime and other fertility) supported legumes, and protein-rich, mineral-rich grasses grew naturally there, to feed the bison; and they are still growing to feed much of our livestock today.

Similar soils are still standing up under heavy cultivation and heavy fertilization. The soil as fullest nutrition is still much of an unknown in terms of the organic matter we grow. Little research is in progress to learn what the vegetation we produce is doing for organic matter in the soil, to serve as nutrition for the microbes there, and as nutrition for succeeding crops in terms of the organic compounds their roots take up to improve the feed and food values of crops.

**Limestone on humid soils helps crops help themselves.** Soils which are well stocked with both lime and organic matter will mobilize both the inorganic and organic items of fer-

tility into crop growth more effectively. Studies using the colloidal clay technique by which the supply of exchangeable nutrients in sand-clay substrata for growing test crops can be accurately controlled, have shown that the concentration of calcium on the clay must hold high the activity of this element if the root is to take nutrients from the soil into the plant generously, rather than allow nutrients like nitrogen, phosphorus, and potassium to go from the plant back into the soil.

With a low degree of calcium saturation in the soil, there was plant growth, but less nitrogen, phosphorus, and potassium were found in the total plant than was originally in the planted seed. It has also been shown that, as the calcium in the soil was present in an increasing ratio to other fertility elements, many of the latter were mobilized into the plant to an accordingly higher percentage taken from the soil's supply and to a greater total and a greater concentration in the crop.

The fact that the help given the plant root allows the root to help itself the more, suggests that it is so enabled when the help given makes more protein in the plant and therefore in the root. In experiments with legumes, some of the plants were inoculated with nodule-producing bacteria, while others were not so treated, but were kept from the chance to get nitrogen from either the atmosphere or the special soil growing them. The nodulated plants of higher protein concentration moved a higher percentage of the fertility supplies off the soil and into the crop. Inoculated legumes removed more fertility off the clay. They exhausted the soil fertility to a lower level; but they made plants more mineral-rich and more protein-rich.

Protein production in the plant helps it because the higher concentration of the protein-colloid in the root takes more ions of fertility from the clay colloid in the soil. Thus, giving the legume some calcium to help it in making more protein within itself, aids in making more of the other fertility elements in the soil available.

When the different amounts of calcium on the clay are associated with differing amounts of other nutrient elements, the influence exerted by each on the other for the amounts moving into the plant vary widely. The amount of any inorganic ion going into the plant depends much on "the company it keeps" with other

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ions on the clay. When those "other ions" are organic ones, the inorganic ones are influenced to get into the plants in proportion to the amounts on the clay. This is particularly true of calcium, which moves into the crop according to the total calcium, rather than its percent of saturation on the clay. (See illustration, p. 128.)

Only recently have we learned that the roots of plants take up organic compounds within which inorganic elements are combined. This means that these inorganics are taken into plants when, in the absence of the organic compounds, they are suffering deficiencies of these particular inorganic essentials. This has been demonstrated by some organic compounds especially synthesized in the laboratory. These synthetic organics moved into the plant simultaneously with the inorganic elements, and resulted in the plant's growth. Whether the improvement was due to one, the other, or both is not fully understood.

This reaction of linking an inorganic element into an organic compound with resultant beneficial effect in plant nutrition is known as "chelation". In an experiment the root system of a plant may be divided between two containers, in one of which the inorganic ion is failing to be taken up by that half of the root system of the plant, demonstrating that failure by plant symptoms. The chelating organic compound may be applied to the other container, or to the remaining half of the root system, and it will go through that into the first half of the root system. The

previously inactive, inorganic ion will be mobilized into the roots and bring about the removal of the deficiency symptoms. Extracts of decaying organic matter have demonstrated that they may serve as natural chelating agents, or mobilizers.

These facts suggest not only that organic compounds resulting from decay of previous crop residues are taken up by the roots for plant nutrition—as we know it for mushrooms, for example—but that decaying organic matter as a chelating agent may be the means of making inorganic elements of soil fertility serve more effectively in plant nutrition.

Thus, when the cold soil of winter is warmed in the spring to start the processes of organic matter decay, those chemically dynamic processes are not only liberating carbonic acid to exercise its possible benefits as an anion in the soil, but also discharging carbon dioxide into the atmosphere, concentrating it in the air layers just above the soil around the plants as possible helps for increased photosynthesis. One scarcely appreciates the large amounts of organic matter decomposed in highly fertile soil, and the large amounts of carbon dioxide liberated by the soil, for example, under a high-yielding corn crop. As a simple comparison one may liken the soil dynamics of organic matter combustion in mid-summer in a 40-acre corn field to the coal fires under a 40-hp. steam boiler.

Organic matter decay also provides organic compounds which nourish plants in much the same

manner as mushrooms live mainly on the organic fertility from the composted layer of manure in the bottom, but are nourished by the mineral fertility from the layer of "casing" soil on the top of the mushroom bed. Then, too, this organic decay is also a chelating process enshrouding less active inorganic fertility elements, like iron, and compensating for their inactivity when left in purely inorganic forms. These conversions within the soil require lime for the microbes, and it brings them about to meet the requirements for their life processes, just as lime is needed in plant life processes.

**Limestone leads all soil treatments.** Lime, as calcium carbonate, puts this major nutrient cation on the clay of the soil. It is the mobilizer of many nutrients, both cations and anions, into the plant. It supports the production of proteins by which plant roots are more effective in taking the adsorbed inorganic fertility from the clay. It is also an essential in the growth of organic matter in the soil and in the microbial transformations there which provide organic nutrients for crops and organic chelators of the less active inorganic fertility ions.

Now that we have learned that limestone on our soils helps because of its calcium, we need to determine whether it may also help because of its provision of carbonic acid, and because of its significance in growing an organic matter of higher values in feeding the succeeding crops, as well as in feeding livestock and ourselves.

