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It's the Calcium . . Not the Alkalinity

● *Missouri tests belie old beliefs about legumes*

By DR. W. A. ALBRECHT
University of Missouri

NORMAL development of plants, like any other growth performance, is distinctly a matter of proper nutrition. Nodule production on the roots of the soybean plant, and its use of nitrogen from the atmosphere to let this crop serve as a protein-producing, and a nitrogen-fixing factory on the farm, are determined in the main by the nutritional levels or the fertility conditions of the soil.

Of the 14 chemical elements required to construct plants, 11 must be supplied by the soil in case of the non-legumes. One less, or 10 are demanded from the soil by the legumes. The legumes, in the same manner as the non-legumes, use carbon, hydrogen and oxygen provided by air and water. In addition, and quite different from the non-legumes, they can take a fourth nutrient—nitrogen—from the air provided they are operating in co-operation with the proper bacteria on their roots commonly supplied as inoculation.

Forgotten Ten

Much of the attention to the behaviors of legume plants and their accompanying bacteria has centered about the fact that legumes can draw, on the weather, as it were, for four of their nutrient requirements, while non-legumes are limited to three. Little attention has gone to the fact that legumes must still obtain 10 (possibly more) nutrient elements from the soil. *Demand made on the soil by the legumes for these elements is greater than by the non-legumes because the mineral contents of legume forages are of higher concentrations.* These demands are more significant because on these increased mineral contents drawn from the soil fertility store there depends the effectiveness with which the root nodule producing bacteria will work.

Because the soybean can go, via bacteria, to the atmosphere for its nitrogen supply, we must not fix attention so completely on this escape from one responsibility as to forget the 10 others that still lie in the soil. Studies to date have not given sufficient importance to all the soil-borne plant nutrients as these influence inoculation, nodule production and nitrogen fixation by legumes. Critical attention has gone to some, namely: calcium, phosphorus, magnesium and potassium, the four most prominent in the soil fertility list. Consider the importance of these in connection with the soybean.

Calcium

Since long ago the art of agriculture has been pointing to the need for lime by many soils if they are to grow legumes. Nodulation of soybeans is generally improved by the practice of liming. It is only recently that science has begun to understand the function of liming for better cooperation between the plants and the bacteria. The scientists' first suggestion as to the role of liming soils in giving better legume growth was that lime was effective because it removed soil acidity.

This explanation is about to lose its adherents, in the face of the accumulating evidence that liming serves because it supplies the plants with calcium, one of the foremost soil requirements for both legumes and non-legumes.

Legume bacteria, too, have been considered sensitive to soil acidity. Failure of inoculation has often been ascribed to injury to the bacteria by the soil sourness. Successful inoculation, or ample nodule production, however, involves more than the idiosyncracies of the plant and bacteria. It involves, most decidedly, the soil as it nourishes both of these properly and sufficiently to make their joint activities result not only in a crop of larger tonnage but one of increased concentrations of proteins and minerals.

Since the soybean must be provided with its specific nodule bacteria when seeded on a soil for the first time, naturally the practice of inoculation of the seed is a recommended one. Failure of inoculation to produce nodules in many instances has brought blame on the bacterial culture, which, like water over the wheel, was past recovery or beyond defense when once distributed throughout the soil. It seemed a logical hypothesis that defective plant nutrition because of soil fertility deficiency might be prohibiting effective inoculation.

Calcium Role Checked

In order to test the nutritional value of liming for the soybean plants as compared to the role of lime in neutralizing soil acidity as these two effects encouraged better nodulation, calcium as a chloride was drilled with soybeans in comparison with similar drilling of calcium hydroxide. *Though the latter neutralized soil acidity while the former did not, both treatments brought about effective nodulation, deeper green color, and larger plants of more stable cell structure.* The nodules were not necessarily located in the soil areas into which the calcium compound was deposited. Roots in the acid soil areas bore nodules. Here was evidence that liming was improving the results from inoculation because lime was providing calcium.

In order to separate the nutritional values of calcium for the plant from those for the bacteria, more detailed tests of the soybean and its calcium needs were undertaken. It was readily demonstrated that calcium was more important than magnesium or potassium in the early life of the soybean plant.

A deficiency supply of calcium encouraged attacks on the plants by a fungus resembling "damping off," and brought failure of inoculation.

To determine the minimum amounts of calcium required per plant for effective establishment of the stand, calcium was used in the solution form and in the form absorbed on colloidal clay. The latter method permitted variable amounts of clays at different degrees of acidity (pH). It thus permitted controlled amounts of calcium at any pH or degree of acidity desired. *These trials demonstrated that the soybean's early growth was dependent on a significant supply of calcium more than on a particular degree of soil acidity.* Nodulation could not result later unless liberal levels of calcium were provided early to carry the plant to the inoculable age. More detailed separation of the calcium as a nutritional element from its role in modifying the soil's reaction as this influences nodulation was undertaken by using acid clay neutralized to different pH values or degrees of acidity through titration with calcium hydroxide.

pH Varied

Constant amounts of calcium were provided at different pH values by taking the proper amount of clay at a particular pH. Thus by placing these different amounts of the clays of different pH values into sand for soybean growth, there were provided soils of variable pH but of constant supplies of exchangeable calcium. Plant growth and nodule production showed clearly that even though the soybeans reflected their response to differences in soil acidity, they reflected far more their growth and nodulation response to the amount of calcium provided.

Nitrogen fixation, or an increase of nitrogen in the crop over that in the planted seed, did not occur even in a neutral soil unless the supply of calcium was ample. It occurred in acid soils containing liberal supplies of exchangeable calcium. *Here, then, was distinct evidence that if inoculation of soybeans is to be effective in making this crop serve for soil improvement, the soil must deliver calcium to these plants.*

Competition

We may well imagine competition between the soil and the plant for the lime. The absorbing power of the soil for nutri-

ents like calcium, potassium, magnesium and other substances is appreciable. It was demonstrated by means of better soybean growth, nodulation and nitrogen fixation, that placing the calcium on a small amount of soil to saturate it highly is more effective than is placing it on much soil to increase the soil saturation only slightly.

These effects from variable degrees of saturation of the clay by the plant nutrient demonstrated similar results regardless of whether the variable calcium was accompanied by acidity or by neutrality. The soybean growth proved that it was not the acidity that disturbed plant growth, but that it was the deficient soil fertility commonly present when soils become acid. Likewise it demonstrated the more efficient use by the plant of the applied calcium in a soil more highly saturated by it. It also suggests a higher efficiency for drilling soil treatments than for broadcasting them.

That calcium is needed for the legume bacteria as they live independently of their host has become a well known recognized fact. With limited lime supply they become abnormal, and fail to inoculate. But given plenty of calcium, they grow well and are effective inoculators.

Unless both the plant and the bacteria have access to calcium, effective inoculation can not be expected. Lime for a legume—even an "acid tolerant" plant like the soybean—plays a helpful role because it nourishes the plant rather than because it removes soil acidity. Even an acid soil must supply lime for successful inoculation and growth of the soybeans.

Phosphorus

Phosphorus, like calcium, is a requisite if soybeans are to be active in nodule production and in nitrogen fixation. But its importance and behavior are closely related to the amount of calcium. Unless calcium is amply supplied, soybeans are poorly nodulated, and are poor nitrogen fixers for soil improvement. In fact they may even lose phosphorus back to the soil, so that the final crop will return less phosphorus when harvested than was in the planted seed.

Magnesium

That magnesium should be helpful toward better soybean inoculation has not come to our attention because relatively little magnesium is required by the plant, and most soils are not seriously deficient in this nutrient. This element is effective on soybeans, but probably indirectly as well as directly. It makes calcium more effective, and thus illustrates the fact that fertility elements work together. These effects suggest an interstimulation among the elements, so that the final results can not be considered, merely as additions of the values of their effects when applied singly.

Potassium

Improved inoculation may also be dependent on the potassium supply in the soil. Experimental studies demonstrated increased nodule production and better growth as potassium deficiencies of the soil were remedied. With more liberal amounts of potassium, however, particularly in contrast to the amount of calcium, inoculation may be less effective and give reduced nodulation and nitrogen fixation. Excessive potassium in relation to calcium makes the soybeans produce more tonnage, but they fix less nitrogen and become more clearly non-legumes than legumes. They move into the class of woody vegetation, and out of the class of vegetation with high protein content of high nutritional value as animal forages.

Inoculation, or the introduction of nodule bacteria with the seeding of the soybean, is not necessarily a practice that will compel the plant to accept the companionship of the bacteria. The latter can not use cave men tactics. Rather, the plant and bacteria will unite in their efforts toward getting their necessary nitrogen out of the gaseous supply in the atmosphere only when the soil provides liberally of all the nutrient elements required by both the plant and the bacteria.

Successful soybean growth on soils of declining fertility can not be guaranteed simply by the introduction of a few particular pedigreed microbes. The plant must first be healthy because it is well fed with calcium, phosphorus, magnesium and other soil-contributed elements. Unless it is well nourished by the soil, the inoculating bacteria will not associate with it to give it the one distinguishing character so desirable in legumes, namely, nitrogen fixing capacity.

Inoculation, or the introduction of the bacteria, is no substitute for the high levels of soil fertility that are demanded for successful legume crops.