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Let's Live Magazine, January, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Bacteria Help Legume Roots Mobilize Fertility

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
Prof. Emeritus of Soils, College of Agriculture, University of Missouri, Columbia, Mo.

Part VII

CORRECTION . . . On page 46, second column, line 18 of Dr. Albrecht's November article, the figures as per cent were repetition of those as milligrams. The corrrected figures should be 8.1, 7.4, 5.6, and, 7.4 per cent respectively.

When the hotel menu sets the price of the dinner according to the meat, fish or eggs you choose, one is reminded that we, like all forms of life, are constantly faced with a struggle for the necessary proteins.

In feeding livestock, the protein concentrates are, as supplements to the carbohydrate crops we grow on many soils so widely, a serious economic problem. Whether we are growing the garden or the field crops, enough of nitrogen, and also calcium, phosphorus, magnesium, potassium and all else of the inorganic elements that must accompany the nitrogen, represent the plants' struggle to make its protein.

Protein carries life

Since it is the protein which carries life in its compounds in any living body or tissue, the struggle for proteins is simply the struggle to survive. If the living tissue of the microbes, plants, animals and man cannot add protein unto itself, it cannot grow, protect itself or reproduce its kind.

Plants may survive at low concentrations of proteins in their tissue by requiring less from the soil. But then what they are has less food value for animals consuming them.

Legume plants, which require--as we well know--much fertility from the soil, will use not only such to build more protein for higher nutritional services to livestock eating them, but they will also use the microbes in their nodules on the roots to make those parts of the plant more efficient producers of the plant's parts above the ground. Legumes can create and contain so much higher concentrations of proteins than the non-legume plants because their nodule bacteria make the roots more efficient in taking fertility from the soil via the extra nitrogen taken from the soil atmosphere.

Problem of balancing

Because legume plants contain higher concentrations of protein in relation to their concentrations of carbohydrates than non-legumes do, the former as forages are used as protein supplements to the latter to give the animal more nearly a balanced ration for efficient nutrition. Just as there is a problem of balancing the ration for the animal, so there is the problem of balancing the fertility for the plant in order to have protein of biosynthetic origin in the plant tissue to balance the carbohydrates of photosynthetic origin.

Calcium (and phosphorus) are associated with the plant's production of the proteins, especially so in the legumes: Potassium is associated with the plant's production of the carbohydrates. Consequently the ratio of the calcium to the potassium in the soil growing the crop must be considered in balancing the nutrition of it to make proteins rather than mainly carbohydrates. Balancing the diet of the plant--regardless of the kind of plant--must be planned as a way of managing the crop's nutritional quality rather than only its quantity a yields.

On the humid soils of Eastern United States, limestone as addition of calcium (and magnesium) to the soil is our major fertilizer. As a pulverized natural rock it is the chemical means of encouraging the plants' synthesis of proteins. Such is the case for both legumes and non-legumes.

Bacteria-producers

But for the higher concentrations of proteins in the legumes, the bacteria-producing nodules on the legume root must also be active on the soil as well as the higher fertility. These microbes bringing nitrogen from the atmosphere to give higher concentration of protein in the roots, make those subterranean parts of the leguminous plants more efficient feeders of themselves, to grow the entire plants more efficiently.

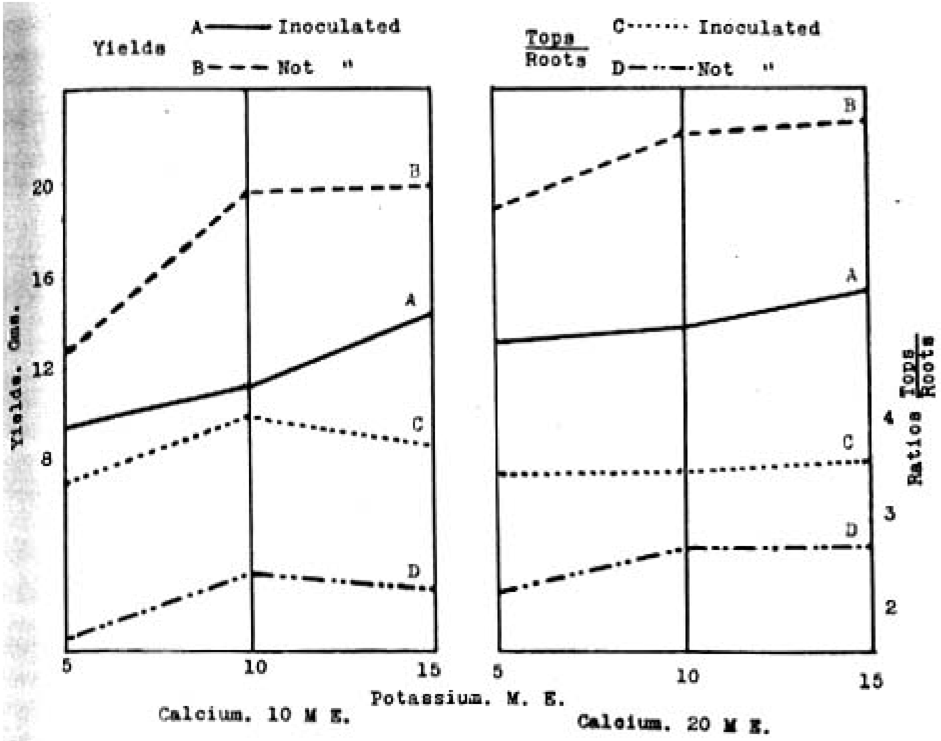

FIGURE I . . . By increasing the potassium in the soil, the yields of the inoculated soybeans (Line A) were reduced below those of the not-inoculated beans (Line B, higher on the scale). The former plants, making more proteins, were not piling up plant bulk as rapidly as the latter. The ratio of plant tops to roots of the inoculated plants was wider (Line C, higher on the scale) than those of the uninoculated plants (Line D).

In an experimental attempt to demonstrate the truth of the above hypothesis, the clay separated out of the soil was electrodialyzed and given different treatments to let it carry calcium--in amounts of 10 and 20 milligram equivalents (M.E.) per soil unit. Then with each of these amounts of calcium on the clay, there were combined 5, 10, and 15 M.E. of potassium as the soil units for growing soybean plants. Then sets of each of these series were given inoculations of the nodule-producing bacteria, while corresponding sets of the series were kept sterile of those bacteria.

The plants of the inoculated series used nitrogen from the soil air, to be added to the plant's nitrogen from the seed. Those series produced plants of high concentrations of protein.

The sterile series of plants were limited to the nitrogen supply originally in the seed. The former behaved physiologically like legumes do naturally. The latter plants, though classified as legumes by their pedigrees, were compelled to behave physiologically like non-legumes because of the absence of nodule-forming bacteria.

Yields

It would not commonly be granted that even for plant yields, we can apply the old adage which says, "More precious things come in smaller packages." Nevertheless, such was the case of the inoculated crops grown in these tests. As normal legumes taking nitrogen from the air to be higher in concentration of protein, they had smaller yields than the sterile, non-legume crops of soybeans (*Figure I*). This was true whether the increased offerings of calcium (Ca = 10, Ca = 20 M.E.) by the soil gave increased yields, or whether the increased offerings of potassium (5, 10, and 15 M.E.) gave similar effects.

These results tell us forcefully that by using only crop bulk as the measure of what a legume crop is doing in response to soil treatments, we may be decidedly mistaken about the soil as it is modifying the nutritional quality of the crop as forage feed. It is the *fertility of the soil and not the plant's pedigree,* which determines the nutritional value of what we grow.

Ratio--tops to roots

Another equally significant--but not commonly recognized--feature of the crops in these two series of inoculated and sterile soybeans was their exhibit of different ratios of the masses of their plant tops to their corresponding roots They were making much larger masses of roots in relation to tops when they were behaving as non-legumes than when they were behaving physiologically as legumes. When they were using nitrogen from the air, the root system were small in relation to large plant tops.

Accordingly, the roots, as legume with nodule bacteria, had a greater capacity for taking exchangeable nutrient like potassium, magnesium and calcium from the clay of the soil and into service in the crops. We know that legume contain higher concentrations of these fertility elements, as well as of nitrogen or proteins, than is true for non-legumes. Such differences in the plant compositions and behaviors were brought about in their study when the same species of plant was inoculated by bacteria, of when these modifiers of the soybeans physiology were withheld. By this simple difference in behavior of the crop the roots, behaving as legumes, increased decidedly their capacity to exhaust the soil of its fertility.

Here there were wide differences in the chemical compositions of the crop accompanied by wide differences in the anatomy (roots and tops ratios) accordingly as the soil had certain microbial life or not and had variable fertility. These are differences in the soil sufficient to give decided changes in the chemical compositions and nutritional values of what we grow.

Can one support, then, the contention that the chemical compositions of our crops are not modified by differences in the soil?

(Continued in February)

Let's Live Magazine, February, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Microbes Give Legumes Their Protein Power

by William A. Albrecht, A.B., B.S., M.S., Ph.D.
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Part VIII

In the previous discussion (No. VII in this series), there were cited (a) the lowered vegetative yields of soybean plants, and (b) the higher ratio of plant tops to roots, when the nodule-producing bacteria for this legume were applied to the seed and thus introduced into the soil. The yields varied as more potassium and calcium were absorbed on the clay to be "available" for exchange to the plant roots and yet not be in solution in water for dangerous "salt" effects or for loss in drainage. Those differences in but two elements--the inorganic fertility of the soil and the organic living differences in the microbes present as another and lower form of life accompanying the soybean plants--served to alter both the mass and the anatomy of them.

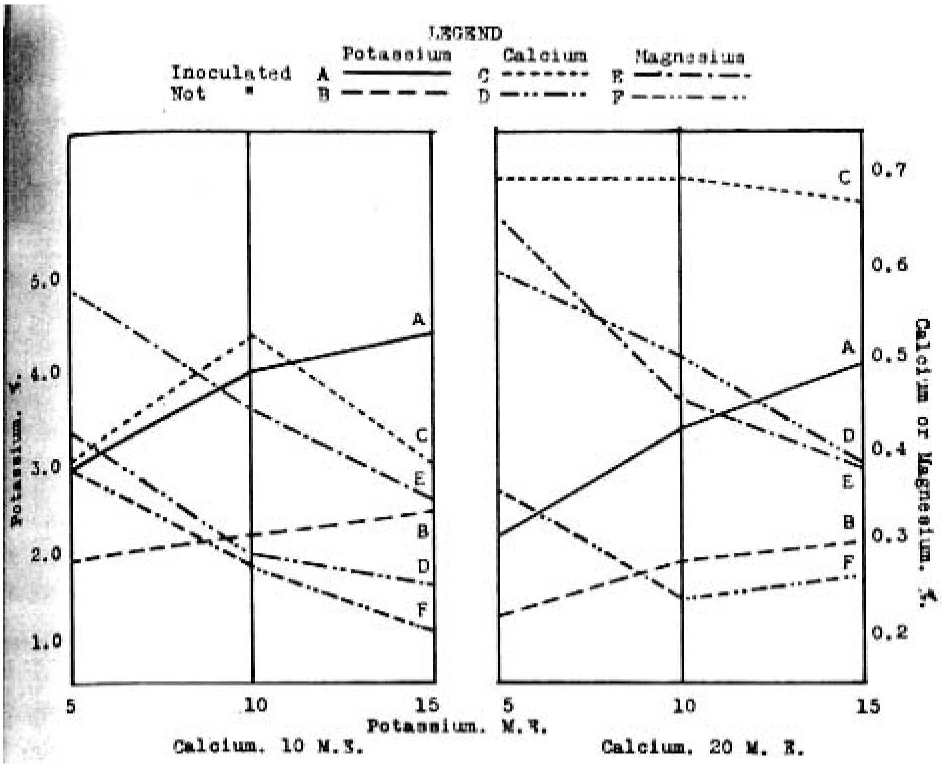
Cause not appreciated

The organic part of the soil as cause of change in the plant compositions has not been appreciated or widely recognized. Some folks, even in national offices of food authority, still insist that even the inorganic fertility of the soil cannot change the chemical composition of the crop, much less its nutritional values as feed and food. The differences in plant composition due to inoculation by microbes serve readily to expose the ignorance of such insistence.

The soybeans were grown as two series, with and without inoculation provided, representing two levels of calcium (10 and 20 M.E.) of which each will in combination with three levels (5, 10 and 15 M.E.) of potassium in the soil. The plants were grown and then chemically analyzed for their concentration of the three cations exchangeable from the clay--namely potassium, calcium and magnesium. They were analyzed also for two anions--phosphorus and silicon. It is sufficient at this time to cite the variations in the concentrations of only the three cations. As the soils were inorganically different--in either calcium or potassium--it is more significant to cite them due to a difference as small as the presence of one single species of microbe, the *root-nodule bacteria.*

Soil differences

The story of the chemical composition differences of the crops is told most simply by the accompanying graphs The left half shows the concentration of potassium as lines A and B; of calcium, as lines C and D; and of magnesium, as lines E and F, according to the varied potassium applied in combination with 10 M.E. of calcium on the soil.



INCREASING THE POTASSIUM of the soil at either the levels of 10 or 20 M.E. of calcium, lowered the soybean's concentrations of calcium and magnesium much less when the plants were nodulated and active in making themselves richer in protein, than when they were not nodulated or were non-legumes.

The first of each of those pairs of lines, namely A, C and E, represents the concentration of the particular cation in the inoculated plants. The second line of the pair, namely B, D and F, represents the concentrations of the cations in the plants grown on soils (or plants) not inoculated, or sterile of the legume bacteria.

The right half of the figure is a similar presentation of the effects on plant composition by these same varied levels of potassium in the soil combined with 20 M.E. of calcium when both are adsorbed on the clay.

The scale of concentrations of potassium is shown on the left side of the figure since it is a higher one than the single scale on the right of the figure suitable for the concentrations of either calcium or magnesium, normally within closely similar ranges of concentrations The different kinds of lines were used by pairs to represent each of the separate cations for plants inoculated and not inoculated, as shown in the legend.

Outstanding fact

The most significant fact exhibited by the graphical picture is the fact that, because of the introduction of legume bacteria into the soil, the soybean plants put higher concentrations of the three cations into themselves. This is clearly shown when the potassium line A (inoculated) is higher on the scale than line B (not inoculated). Similarly the calcium line C is higher on the scale than line D; and the magnesium line E is higher there than line F, regardless of whether the calcium level was 10 M.E. or 20 M.E.

These are decided increases in the capacity of the plants to concentrate more of each of these three inorganic essentials into each unit of vegetation, for example, merely because some particular microbes were present in the soil. Unfortunately, we have not studied the differences which might occur in foods because of other kinds of microbes, present or absent, in soil.

Depression factor

It is also important to note that the concentration of calcium in the inoculated soybean plants was not depressed much by the higher amounts of potassium in the soil, but it was depressed decidedly in the plants not inoculated. The concentration of magnesium in the plants was depressed decidedly by increases in the potassium of the soil, but much more so in the not-inoculated plants than in those inoculated.

In examining the results of this study, we need to remind ourselves that the non-nodulated roots of greater mass per plant had the same amount of clay with which to make contact for plant nutrition as the nodulated roots did. Nevertheless, the concentrations of the potassium, calcium and magnesium were higher in the nodulated plants with less masses of roots per plant, because of cooperative help from the bacteria. Here there were decided differences in the chemical compositions of the plants as the result of a small organic difference--namely, the bacteria in the soil. There were also differences in the concentrations of the calcium and the magnesium in the plants because of differences in the potassium in the soil.

Can one say with truth, then, that the fertility of the soil does not cause the chemical compositions and nutritive values of a crop to vary?

Let's Live Magazine, March, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Fertility Effects Show Early in Plants

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Part IX

The study of non-legumenous plants fails to reveal the force of the soil fertility in bringing about chemical composition differences of plants, which one appreciates more by studying the *legumes* as producers of higher concentrations of proteins and inorganic essential elements. The variation in nitrogen metabolism of the latter may serve as an index of the nutrition elements' irregularities, other than nitrogen. In past articles, the fluctuation in the nitrogen metabolism--measurable by differences in plant growth, degree of nodule production, nitrogen concentration and content, and nitrogen fixation--has been demonstrated influences of other elements such as calcium, phosphorus, magnesium, potassium, etc. on the plants' behavior in accordance with the soil treatments by such and others.

Since legumes do not grow well on the highly developed soils of Eastern United States unless limestone is applied to them--since that treatment is effective not so much because its carbonate reduces the degree of soil acidity, but because its calcium (and magnesium) nourish the plant so much better than is possible on the untreated soil--it seemed wise to learn how early in the life of soybeans (a legume) and limestone would be effective.

Soybean test

Soybean seeds, sterilized to destroy possible nodule-producing bacteria, were planted into calcium-deficient sand. Similar seeds were planted into the same kind of sand given pulverized limestone at the rate of five tons per two million pounds, simulating a heavy application of limestone.

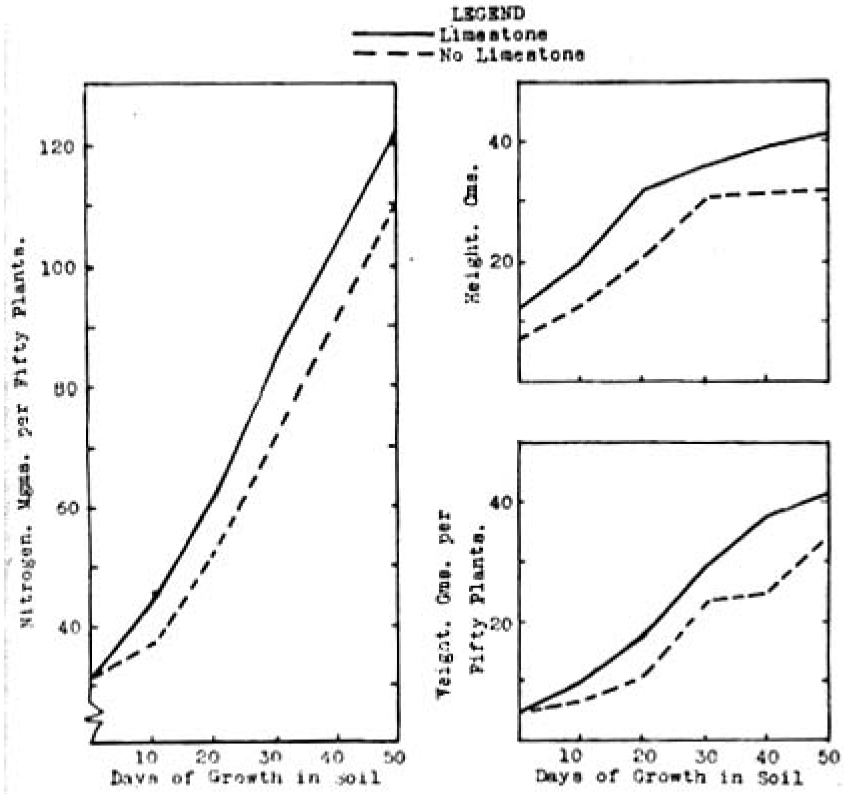
After a 10-day germinating and growth period, these plants were taken up, washed carefully and transplanted as two separate sections into an acid soil (pH 5.5) which had been growing well-inoculated soybeans in the field.

From both halves, harvesting of 50 seedlings each were taken (roots and tops) at 10-day intervals. These were measured for (a) plant height, (b) dry weight, and for (c) nitrogen content from which concentrations could be calculated.

The data for these three criteria of the limestone's effect on the plants' lives, when in contact with the limestone during only the first 10 days of its life, are graphically shown in the accompanying chart. The data include only the time the plants were in the soil. The plant age is 10 days more than the figures used and includes the 10 days germination and growth in the sand.

Test results

It is interesting to note that calcium increased the height of the plants, even if it did not increase their weight. Also the nodules, not graphically reported increased in numbers earlier as the results of the contact with calcium at the beginning of the plants' life. The nitrogen increase in the plant started earlier as the result of the calcium nutrition in those early days of growth.



ACCESS TO LIMESTONE in the soil for only the 10 days of germination and start of growth helped the soybean plants to weigh more, be taller and contain more nitrogen for the next 50 days after transplanting into another soil.

It is quite unusual that the calcium-fed plants increased their nitrogen by 18,4% over the calcium-starved plants during the first 10-day period of growth in the soil, even before they had produced nodules. Then calcium in the roots made them more effective in taking nitrogen from the soil's supply.

During the second 10-day period and advent of nodules, the calcium-fed plants again increased their nitrogen content faster than the calcium-starved ones. The nitrogen increase in the plants fed calcium for the first 10 days of their life over those not so treated amounted to an average of 17% plus for the five 10-day periods measured.

These increases in nitrogen content occurred through increased growth rather increased concentration within the dry matter. This latter was constantly higher in the initially calcium-starved seedlings. Both treatments at the outset in the sand, followed by the in-soil growth, demonstrated the lowering concentrations of nitrogen in the dry matter during these 50 days of plant growth in the soil.

Recapitulation

Here was a clear-cut demonstration that there was (a) lengthening of the plant stems, (b) increased metabolism of nitrogen, (c) production of more chlorophyll resulting in greener color, (d) more nitrogen fixation and other increased physiological changes--all modifying the chemical composition as a result of soil treatment (calcium only) of no more time length than the first 10 days of the seed's life and the seedling taking off to make the plant. Surely there is not much constancy in the chemical composition of plants, when contact with limestone for but 10 days makes such differences for the next 50 days of the plant's life!

(Continued in April)

Let's Live Magazine, April, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Big Yields of Bulk--Low Phosphorus Concentration

by William A. Albrecht, B.A., B.S., MS., Ph.D.
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Part X

Phosphorus is commonly deficient in the humid soils for their production of feed and food crops. Some 20 years ago, an agronomist, J. G. Hutton, reported, "Phosphorus, when applied alone for 30 years, has increased the yield of all crops." (From: *Thirty Years of Soil Fertility Investigations in South Dakota,* South Dakota Agricultural Experimental Station Bulletin 325, 1938.)

Total chemical analyses of the soil were cited then, and earlier, as indication of the shortage there of this less soluble nutrient for all that grows. Phosphates came into use as fertilizers early in the form of bone meal. Later, basic slag from the steel-smelting furnaces, and rock phosphate from the mines, were additional sources to meet the demand for fertilizer phosphates.

"Acid phosphate"

Treatment of bones with sulfuric acid brought the bone phosphorus into more soluble form as "acid phosphate" and helped us to appreciate how rapidly that soluble mono-calcium phosphate reverts to the insoluble tri-calcium phosphate form in soils calcareous enough to grow protein-rich legumes better in consequence of fertilization with phosphorus.

As a negatively charged ion, or anion, phosphorus unites with the divalent calcium, a cation, to be insoluble. It unites with the trivalent elements iron and aluminum to become extremely insoluble. As a consequence, the weak carbonic acid of the plant root is not able to activate those forms of phosphate significantly for plant use. The natural mineral phosphate, *apatite,* is also very insoluble. Consequently, with natural mineral phosphates of the soil so insoluble, or so available to the plant roots--and the total supply of phosphorus in any form in the soil so low--it is readily evident that most crops are growing under a deficiency of this nutrient element.

An anion

Since phosphorus is an anion, we not expect it to be adsorbed on and exchangeable from the negatively charged colloidal clay molecule, as is the case for the cations--calcium, magnesium, potassium, and others. Consequently, we do not have as clear a picture of its behavior in the soil as we do for the cations. Nevertheless, it behaves according to its anionic properties.

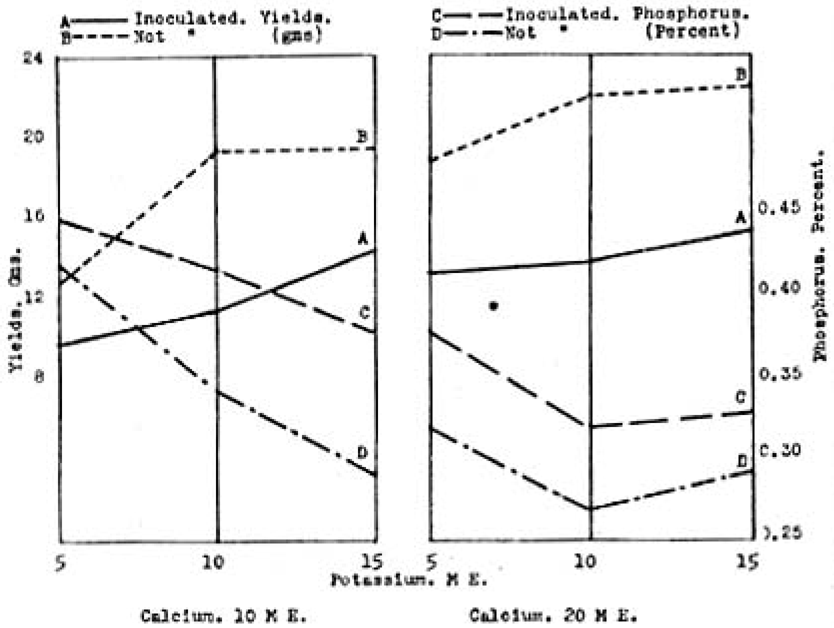

FIGURE I . . . As the vegetative yields went up (Lines A and B), the, concentrations of phosphorus in them (Lines C and D) went down. Also, the concentrations of phosphorus were higher in the inoculated soybean plants than in those not inoculated (Lines C over Lines D).

In the studies of inoculated soybeans, able to use atmospheric nitrogen--as such legumes can to make themselves mineral-rich and protein-rich in contrast to uninoculated soybeans behaving like lion-legumes and limited to soil or seed nitrogen--it was shown clearly that the phosphorus--like the cations--was taken from the soil to give higher concentrates of it in the plants behaving as legumes. There was also a negative correlation between the vegetative yield and the concentration of phosphorus in it. Also significant is the fact that as the potassium in the soil was increased, the phosphorus concentration in the crop was decreased. (See Figure I).

Vegetative bulk

Thus, with our emphasis on bigger yields of vegetative bulk of soybean hay, for which potassium was a help (Figure I), we are not apt to realize that we are also practicing a deception on the animals expected to feed on it. But such is the case, which may be more of a deception of ourselves in the final anaylses. With the increased treatment of the soil with potassium, the concentration of the phosphorus in the forage feed went lower.

Silicon--another anion not yet considered an essential element for man and animals though found in hair, hoofs, and nails--was also lowered in its concentrations in the soybean plants, according as the potassium in the soil was higher. (See Figure II).

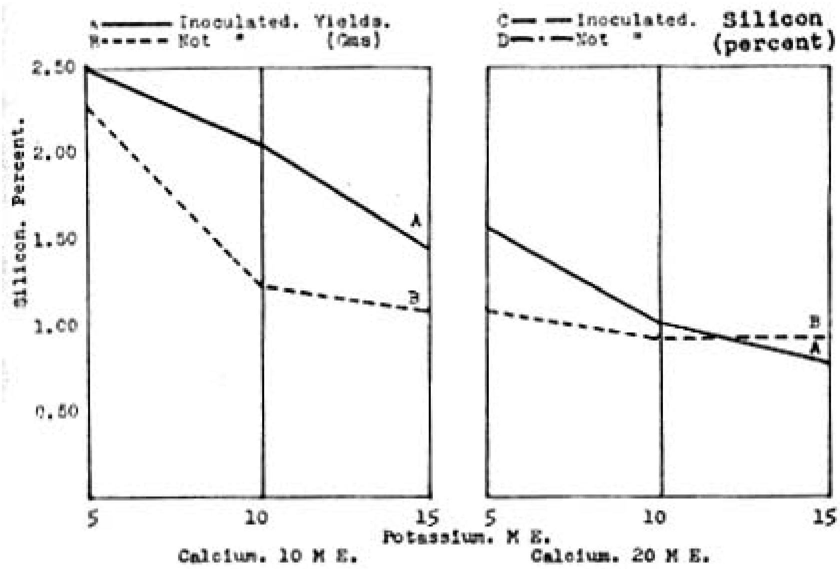

FIGURE II . . . The inoculated soybean plants had higher concentrations of silicon than those not inoculated. Also, according as there was more calcium in the soil, there was less silicon in the plants.

Also, silicon went lower in its concentration very pronouncedly in the plants when the calcium adsorbed on the soil was increased from 10 to 20 milligram equivalents. (Figure II). Silicon, which is the abundant anion in the soil as remnant of decomposing original rock to give the clay colloid, behaves similarly; as do all the other ions, under the "balanced" effect of the whole group in their respective movements into the plant root to make up its part of the inorganic constituents or ash.

Phosphorus and silicon

Phosphorus and silicon, may be included in the list of the many other essential elements as variables in the chemical composition of the crop when the soil is variable even though the plant species (and all else) is constant. Phosphorus varied from a low, taken as one, to a high of one and two-thirds (0.27 to 0.45%). The silicon varied from a low, taken as one, to a high of more than three (0.81 to 2.54%). Since phosphorus is generally low in most any food or feed crops we grow, its variation there brings the serious danger of its being a deficiency in nutrition so much more quickly. Can we believe, then, that the soil does not cause differences in the chemical compositions of plants, and has no possible nutritional effects via the foods we eat? Shall we censure those who would supplement their own diets by organic phosphorus concentrates available in the food stores? Surely one's own nutrition for one's own health is still one of our freedoms.

(Continued in May)

Let's Live Magazine, May, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Boron Interrelated With Potassium

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part XI

In the preceding several articles, the interrelations of one fertility element to others in the soil as they modify the chemical composition of the crops grown have been discussed. But only the major, inorganic elements have been considered.

It is well, then, to look into the balanced diet of the plant so far as the trace elements in balance with the major ones are concerned. As a case in illustration: *boron* in relation to potassium may be of interest.

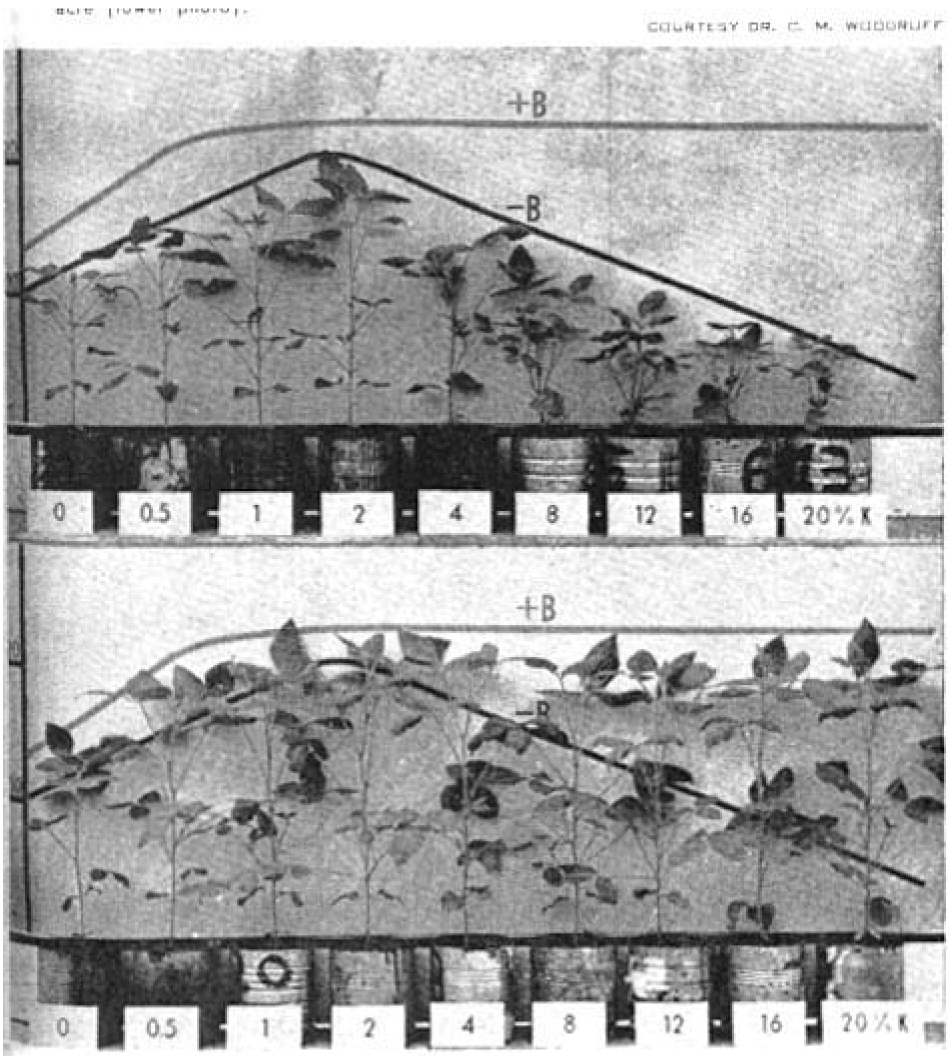
Shortage symptoms

Deficiency of boron in the soil, and thereby in the crops, has recently been given much attention. The symptoms of its shortage have included heart-rot of some root crops; high sugar in the leaves but low sugar storage in the sugar beet; and high starch in the leaves of the potato plant but small tubers and poor starch storage in them. While such symptoms represent ample carbohydrate production, there is a failure--probably of its conversion into protein, as one might theorize from the failure of alfalfa, a high-protein forage--to develop its tips of the plants or the areas of growth where protein would seem to be failing.

When the trace elements seem to play their roles in the enzymes as protein-like substances, those are more plentiful in connection with growth processes involving regular proteins than they are in carbohydrate synthesis and storage.

Synthesis and function

The closer connection of boron with the synthesis and functions of proteins is suggested by the recently presented evidence of boron's essentiality for warm bodied life, namely animals and man. The skin irregularities connected by boron in the diet suggest that this enormous excretory organ outside of the body is not functioning as it should when eczema and mange in animals and acne in humans are remedied if boron is taken by mouth in solutions of borax. Professor C. M. Woodruff of the Soils Department of the University of Missouri, with the help of H. Sinha of India, demonstrated the necessity of having boron in the soil, if higher applications of potassium were not to be damaging to the growth of the soybean plants. In the absence of boron, the potassium at but 2% saturation of the soil's exchange capacity was the limit of beneficial effect by this monovalent cation. Larger amounts reduced the growths of the plants. But when but one pound (or two) of the element boron were used per plowed acre of two million pounds of soil (1 p.p.m.), the increased applications of potassium, up to saturation of 20% of the soil's exchange capacity, were without detriment of notice.



APPLICATIONS heavier than 280 pounds per acre of potassium (2% saturation) to the soil for soybeans were detrimental in the absence of boron (-B, upper photo), but were not so when 1-2 pounds of boron per acre as borax accompanied the potassium treatments going as high as (20% saturation) 2800 pounds per acre (lower photo).

In balance--imbalance

Thus the plant's ration was given an increase of potassium by 10 times and yet that plant ration was "in balance" to all appearances with other major elements when the trace element boron was present in the ratio as small as one part to 2800 of potassium. In the absence of boron, 280 pounds of potassium per acre were the upper limit of the plant's use of this element with good effects on vegetative growth.

This imbalance in boron absence disturbed also the plant's uptakes of calcium and magnesium, usually considered requirements in the soil at 75% and 7.5% saturations, respectively, of the exchange capacity when in balance with potassium at not more than 3% saturation.

"Team-work"

Nature has a large number of elements going into the plant from the soil. Yet, seemingly, when all are plentifully present along with much organic matter, each may vary over a wide range of apparent excess without noticeable disturbance in the plant's growth. Their "team-work" seems to be excellent. But when one single element is not carrying its full share in plant nutrition, or is in deficiency, then other elements also seem so much more severely out of balance as excess, or as deficiency, when among the major elements.

Dr. Woodruff and his understudies point out that while imbalances in the major fertility elements of the soil disturb plant growth and cause the plant's chemical composition to vary widely, we dare not forget that imbalances between the trace elements and the major ones may even be more disturbing to crop growth and its nutritional values, not only according to chemical analyses of the ash, but also according to tests via nutrition of the warm-blooded animals and man.

(Continued in June)

Let's Live Magazine, June, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Boron Helps Maintain Potassium Balance

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part XII

An illustration of the inter-effects among the amounts of the fertility elements in the soil, on their respective concentrations within the plants grown on the soil, was recently demonstrated at the Missouri Agricultural Experiment Station. This demonstration included the inter-relations among four essential elements: namely, the three major exchangeable cations--calcium, magnesium, and potassium, and the single anion, the trace element--boron. The boron seemed to maintain the balance among them in their going into the soybean plants.

The depressive factor

The study serving in this demonstration revealed the important, but not widely appreciated, depressive effects of the increasing saturation of the soil's exchange capacity by potassium on the uptake of calcium and magnesium by the legume crop of soybeans, when the last two essential elements were of constant exchangeable supplies in the soil. The lowering of the calcium concentration in the soybeans according to the exchangeable potassium increase in the soil is shown in Figure 1 by the graph line labeled "Calcium minus Boron." In the same figure, there is shown the increasing concentration of potassium in the leaves of the soybean plants according as there was increase of exchangeable potassium in the soil, by the graph line labeled "Potassium minus Boron."

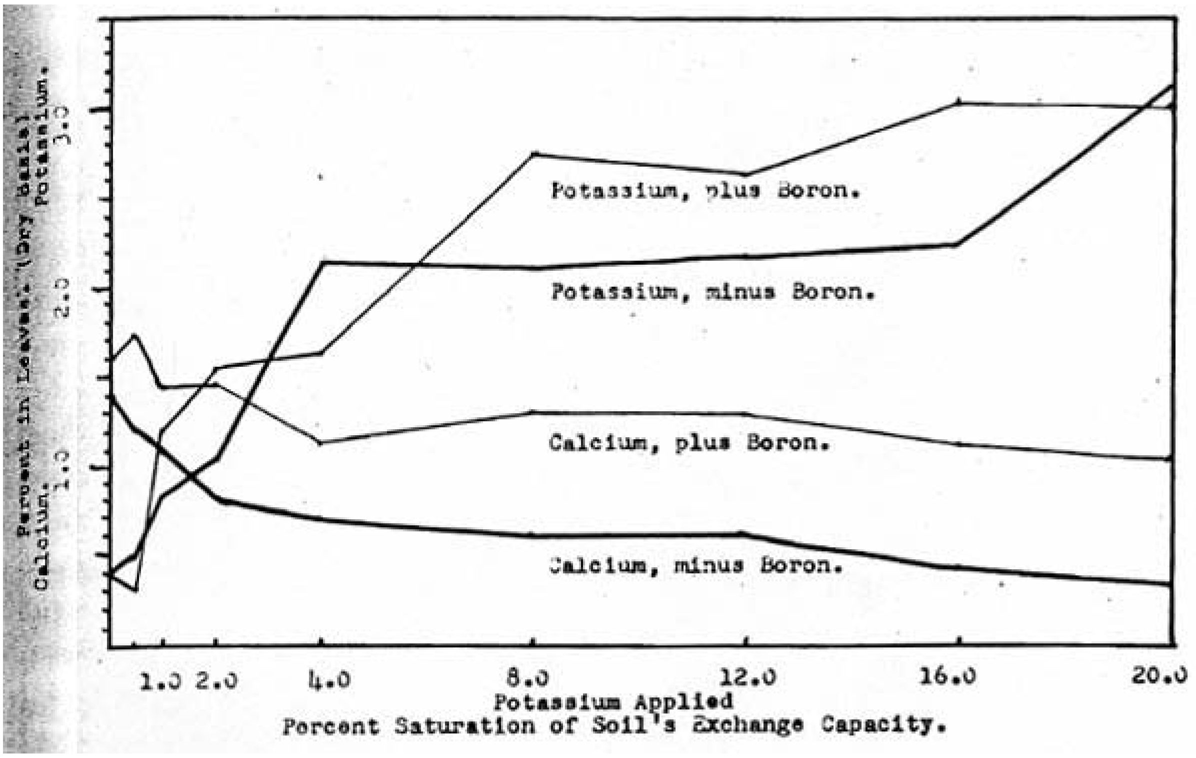

FIGURE I. Increasing the exchangeable potassium in the soil puts increasing concentrations of that element into the leaves of soybean plants (Potassium minus Boron), but it decreases concentrations of calcium in that forage (Calcium minus Boron). But when with that increasing potassium some boron is applied (1-2 pounds per acre), the concentration of calcium in the forage is raised pronouncedly.

It is significant to note, however, that while the increase in potassium concentration in the soybean plants showed up as nearly a straight line function first part of the graph, the corresponding decreasing concentration of calcium did not follow the same pattern in its portion of the graph: namely, an calcium decrease per unit of increase in potassium added to the soil, or per unit of increased potassium concentration in the plants. Instead, the major depressing effects on calcium by added potassium were brought about by the first potassium increments: namely, those less 4% saturation of the soil's exchange capacity. This agrees with the consideration of 3% of saturation by potassium of that exchange capacity as a recommended soil saturation by this monovalent and highly soluble cation.

The above were the facts demonstrated when no boron was added to the the buffering effect of the trace boron against this depressing effect by increasing potassium was the most startling part of the demonstration--when two pounds or less of the element boron were applied per two million pounds of soil. That the presence of the boron in the soil reduced the depressive effects by the potassium on the calcium going into the plants is shown also in Figure 1, by the graph line labeled "Calcium plus Boron."

Boron served similarly to lessen the depressive effects by the potassium on the magnesium concentration in the soybean leaves.

Boron as an aid

When calcium is a major ash element in the warm-blooded animals, and when it is so highly essential to legumes for their greater activities in fixing nitrogen, the boron--as an aid in moving high concentrations of calcium into forage feeds--may be indirectly a very important fertility element. It may be some such similar indirect effects by which we have recently found evidence that boron is itself an essential element for warm-blooded bodies and have cited earlier the inter-effects among boron and calcium in the better growth of the duckweed (*Lemna minor*) common on ponds. It is also significant that boron acts indirectly with similar importance by way of magnesium.

This role of the trace element boron in prohibiting the imbalances between the three major cations, calcium, magnesium and potassium, gives this extremely small amount of an essential element a significance within the soil--plant--root area which we certainly have not yet appreciated. When so little of one trace element as a pound or two per acre balances four essential elements so much more favorably for better growth of the high-protein crop like soybeans, this fact indicates how much of a problem lies ahead before we can feel confident that we can balance the applications of all the essential elements, major and trace, to insure plant compositions which will result as truly nutritious feeds for healthy animals and humans.

(Continued in July)

Let's Live Magazine, July, 1960

DIFFERENT SOILS,
DIFFERENT PLANT COMPOSITIONS

Soil Exhaustion--Variable Organic And Inorganic Composition of Plants

by William A. Albrecht, B.A., BS., M.S., Ph.D.

Prof. Emeritus of Soils, College of Agriculture, University of Missouri, Columbia, Mo.

Part XIII

Depletion of the soil fertility is a serious factor bringing about lowered nutritional quality in the succession of crops on the same soil. This simple fact is not yet widely recognized. It is even denied by some who contend, "There is no scientific basis for the theory that crops grown on poor soil . . . are nutritionally inferior in any way. . . ." (*Food Facts vs. Food Fallacies, World Health Day Kit, April 7, 1957,* Food and Drug Administration, Washington 25, D.C.)

Depletion theory proofs

Chemical studies of soybean plants, reported nearly 20 years ago in the Missouri Agricultural Experiment Station research bulletin No. 330, show how widely three successive crops varied in concentration of (a) their organic compounds--namely sugar, starch and nitrogen (protein); and (b) their inorganic elements--namely calcium, phosphorus, magnesium and potassium. All soil treatments were the same, except (a)--the amounts of exchangeable potassium on the colloidal clay, and (b)--the absence of nodule-producing bacteria from the soil in the first crop, but their presence in the second and third.

The yields of the soybean crops, including the entire plants as both roots and tops, and their organic compositions of nitrogen, sugar and starch as percent-ages of dry matter are given in *Table 1.* The data are arranged in their order according to the increments of exchangeable potassium added to the soil, and to the three successive crops. The inorganic compositions of calcium, phosphorus, magnesium and potassium, each as centage of the dry matter, are similarly in *Table II.* The gains or losses in total nitrogen in the crop (both roots and tops) relative to that initially present in the planted seed are given in *Table III.*

TABLE I

	Potassium ME/ culture 0	Potassium ME/ culture 5	Potassium ME/ culture 10	Potassium ME/culture 15
Yields Gms (1)				
one (2)	14.70	19.32	22.51	22.22
two (2)	10.48	10.38	11.37	13.60
three (2)	11.94	12.36	14.50	12.42
Nitrogen % (1) (3)				
one	1.57	1.24	1.16	1.18
two	3.31	3.34	3.33	3.18
three	2.56	2.68	2.21	2.70
Sugar %				
one	3.89	2.68	2.42	1.31
two	8.68	7.46	8.60	7.69
three	9.08	8.08	8.20	6.86
Starch %				
one	8.39	10.62	17.35	15.52
two	4.21	4.11	4.09	5.19
three	7.16	8.38	11.21	12.84

1. *Gms. represents the grams of dry matter; % represents the per cent in the dry matter.*
2. *Crop one was given no nodule-producing bacteria but crop two was; hence they were present and active in the soil for crop three.*
3. *The seeds for all plantings were from a common lot of genetically similar mother plants.*

TABLE II

	Potassium ME/ culture 0	Potassium ME/ culture 5	Potassium ME/ culture 10	Potassium ME/ culture 15
Calcium %				
one	0.44	0.41	0.41	0.43
two	0.64	0.54	0.53	0.57
three	0.39	0.41	0.27	0.30
Phosphorus %				
one	0.19	0.19	0.20	0.21
two	0.27	0.27	0.29	0.26
three	0.23	0.23	0.20	0.25
Magnesium %				
one	0.34	0.28	0.25	0.23
two	0.20	0.19	0.19	0.22
three	0.15	0.18	0.14	0.16
Potassium %				
one	0.73	1.32	1.68	2.18
two	0.87	1.02	1.38	1.44
three	1.12	1.30	1.05	1.50

TABLE III

Nitrogen--Mgms (1) Gains + Losses-

	Potassium ME/ culture 0	Potassium ME/ culture 5	Potassium ME/ culture 10	Potassium ME/ culture 15
one	-82.6	-76.1	-57.0	-74.9
two	+28	+28	+60	+115
three	-13	+13	+2	+12

1. *The total nitrogen in the seeds planted in each pot was 318 mgms.*

Added positives

As regards the yield data, the following facts stand out clearly:

(a) The largest vegetative yields resulted from the first crop when plants without nodule bacteria were behaving physiologically as non-legume plants and not as legumes, their proper classification according to their pedigrees.

(b) The first crop of the three had less nitrogen in the dry matter than there was in the planted seed. Nitrogen was lost from that initially present in the seed and by the amounts shown in *Table III.* Those losses ranged from 14.7% to 26.1% of that initially planted.

(c) The yields of the second crop (the first inoculated crop, behaving as a legume) were the lowest, in total, of all three crops. Yet this crop used atmospheric nitrogen for its growth, in amounts ranging from 8.8% to 36.1% increases over what was initially planted in the seed. In terms of crude protein, ft was the most nutritious forage.

(d) The third crop--in spite of the fertility depletion of the soil by two previous crops--was still taking atmospheric nitrogen for its nutrition of the inoculated legume plants, save for the one case where no exchangeable potassium was added to the colloidal clay. (*Table III*)

According to these data, the fertility and the bacteria of the soil--not the plant pedigree--determined whether the plants behaved as legumes with reference to their use of atmospheric nitrogen and their delivery of varied concentrations of protein as quality in nutritional values.

Relative to the changing organic compositions of the crops in succession and with depletion of the soil fertility, it is well to note the following facts:

(a) The low concentrations of sugar, but the high concentrations of the starch in the first crop suggest a non-legume physiology in which the carbohydrates of photosynthesis are quickly converted from active forms as sugar into inactive storage forms as starch.

(b) Conversely, the second and nodulated crop suggests its physiology as a legume by its high concentration of sugar but low concentration of starch--with the former awaiting biosynthesis into protein through extra nitrogen fixed from the atmosphere which is suggested by the data in Table III and by the concentrations of nitrogen (average 3.29% in the dry matter) in Table I--representing nearly the double of that in the first crop (average 1.28%) behaving as a non-legume.

(c) The third crop also had a high concentration of sugar, but a higher concentration of starch--with the latter suggesting the failure of conversion of the sugar into proteins as a sequel of the depletion of the fertility. The failing nitrogen fixation is suggested by the one negative and three small, but positive, figures for the increases of total nitrogen in the third crop over that in the seed.

Relative to the changing inorganic compositions of the successive crops, it is significant to note that:

(a) The calcium concentration in the second crop behaving as a legume was about a third higher than that in the first, a non-legume in behavior. The calcium in the third crop, also acting as a legume, was lower than that in the first crop, indicating depletion of the soil of calcium, the element required generously by legumes active in nitrogen fixation.

(b) The phosphorus concentration in the soybean plants was increased by the inoculation or by leguminous physiology, to carry this effect to the third crop, as a more nutritious feed in terms of concentration of this element.

(c) The magnesium concentrations in the crops declined as the soil was given more exchangeable potassium, and with the succession of crops.

(d) There was a decline also in the mean concentrations of potassium with the successive cropping.

According to these data of chemical compositions of the soybean crops--both organic and inorganic--there is certainly some "scientific basis for the theory that crops grown on poor soil . . . are nutritionally inferior . . ." in terms of the important food compounds they synthesize and of the concentrations of essential elements which they supply. There is also evidence that successive cropping of the soil depletes its fertility in terms of the elements supporting protein production by the crop.

(Continued in August)

Let's Live Magazine, August, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Sulfur Deficiency in Soils

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part XIV

Each living cell or body of them, from the lowest form to the highest, is struggling for its necessary proteins. Only the two simplest forms of life, the microbes and the plants, are able to assemble those living compounds from their component chemical elements and into their particular group of amino acids--with each amino acid in such amounts characterizing the proteins.

Of the nearly two dozen such acids--in combinations--making up most proteins, the majority consist of the elements carbon, oxygen, hydrogen and nitrogen. But as a rule, a small part of the protein consists of amino acids carrying also some sulfur.

We have emphasized nitrogen as the distinguishing element in protein and have called concerted attention to the nitrogen deficiency in the soil for the growth of proteins in our crops. But we have not shown much concern about sulfur as a necessary fertilizer element. We have not considered it for measure when we test soils for their supply of fertility elements, to which list sulfur belongs.

Positive factors

The sulfur aspect of the proteins, in terms of but one or two amino acids, deserves particular concern for two reasons. First: these sulfur-containing amino acids are compounds specifically required for life. Second: sulfur in compounds closely related to them serves in the process of cell division, or in creation.

In that process of the multiplication of cell tissue as growth, the sulfur, linked with hydrogen and carbon, is the unit of particular essentiality. After the increase of the cell in volume, its increased concentration therein of the sulfur part marks the initiation of the cell's division to give two new cells. The reproduction, more than the growth as volume, seems to reside in that sulfur compound.

The consumption of coal (now decreased by the use of gas) once put much sulfur dioxide into the atmosphere, to be brought down into the soil by rainfall. And since sulfur has been in combination with ammonia in fertilizers and mixed with the more soluble phosphates, we have not concerned ourselves about sulfur deficiencies in our crops. These deficiencies, because of soil deficiencies, have not emphasized themselves by any seriously reduced yields of crop bulk. But that fact does not prove, however, that sulfur shortages in the soil's fertility have not shown up in both the quantity and the quality in the crop's "crude" protein, insofar as the balance of essential amino acids is concerned in those forage crops used A animal nutrition.

When deficient

When the sulfur supply in the soil becomes low, there occurs a decided reduction of the sulfur-carrying amino acids, like cystine and methionine; but more seriously, a pronounced reduction in the plant's contents of nearly all the amino acids, or of the *total* proteins. These are the facts according to studies of the leguminous crop, alfalfa--so widely used as the protein "supplement" to other crops as feeds. These facts were set forth in research at the Indiana Agricultural Experiment Station. . .

(E. T. Mertz, V. L. Singleton, and C. L. Garey, "The Effect of Sulfur Deficiency on the Amino Acids of Alfalfa," Archives of Biochemistry and Biophysics, 38:139-145, 1952.)

The sulfur-deficient soil produced alfalfa with concentrations of slightly one-third more cystine and one-half more methionine of their concentrations in the crop's dry matter grown on a normal soil, as regards its sulfur supply. (See table.) The concentrations of the other required amino acids in the alfalfa crop grown on the sulfur-deficient sub-stratum were only one-third to one-half those in the alfalfa grown on the normal soil. (*See table.*)

The Amino Acid Composition of the Third Cutting of Alfalfa Grown on Normal soil and also on Sulfur-Deficient Soil.
(Percentage Dry Weight)

Amino Acid	**Normal**	**Sulfur Deficient**	**Deficient ÷ Normal x 100**
Sulfur-Containing Amino Acids			
Cystine	0.46	0.18	39
Methionine	0.29	0.15	51
Other Essential Amino Acids			
Histidine	0.36	0.24	66
Lysine	0.89	0.53	59
Tryptophane	0.37	0.17	45
Phenylalanine	0.96	0.52	54
Leucine	1.82	0.95	52
Isoleucine	0.86	0.54	62
Threonine	1.16	0.57	49
Valine	1.09	0.62	56

Conclusions

Here again, as in the other cases cited in this 14-part series of reports, the deficiency of one element in the soil--one not even considered when we test soils or use fertilizers--was responsible for a decidedly low concentration of organic compounds, their life-carrying proteins, created by plants.

Even more significant was the fact that besides sulfur-containing amino acids, others were of low concentrations in the alfalfa grown on sulfur-deficient soil. This suggests that the sulfur may be playing a role in the plant's synthesis of most all the amino acids. Thus sulfur is needed both as a constituent element of these proteinaceous organic compounds and as a tool in the synthesis of them. As a consequence, the organic composition of the crop may vary widely when shortages of a fertility element means shortage of that element for organic construction, as well as of tools for the fabrication of other organic compounds.

We not only need concern ourselves about our foods after they are grown, but much earlier. Primarily, about our foods nutritional *quality* as determined by the fertility of the soils growing them. Only our ignorance of what the soil represents, as the foundation of life, will let us believe and contend that the soil is of no influence on the nutritional quality of crop growth.

(Continued in September)

Let's Live Magazine, September, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

Chemical Composition of Plants and The "Feeding Power" of Their Roots

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
Prof. Emeritus of Soils, College of Agriculture, University of Missouri, Columbia, Mo.

Part XV

In nature's ecological settings, the plants are nourished in three ways: (a) by decomposition of naturally pulverized rock-fertilizers; (b) by exchangeable nutrient elements adsorbed on the clay- and humus-colloids; and (c) by elements and compounds liberated from decaying organic matter of microbial and plant origins.

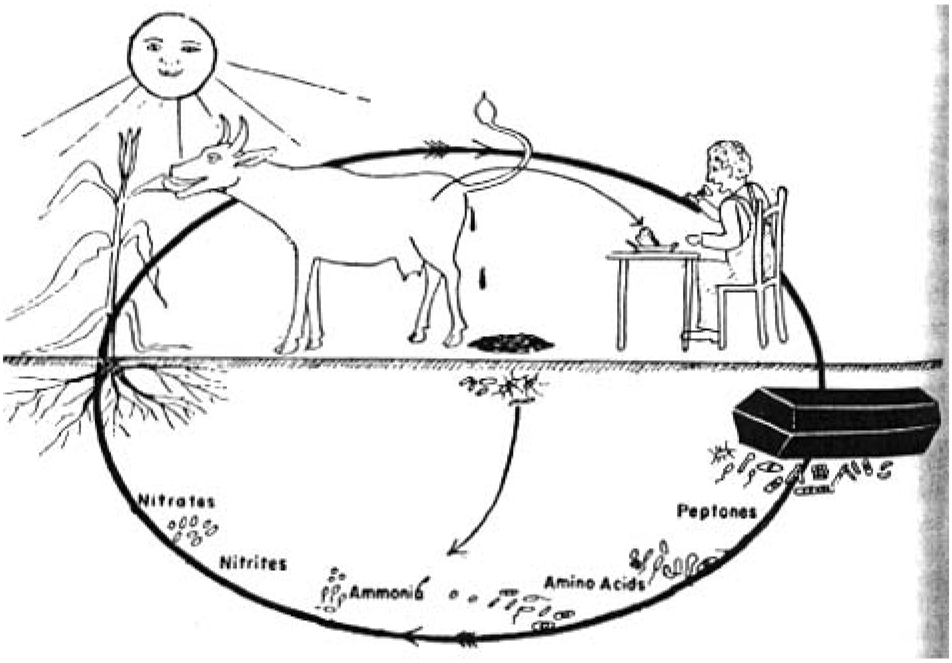
Relative to the first of those sources, critical studies* have given us the concept that particles of granite minerals of near clay-size will break down in water, in acids, and in salt solutions to be adsorbed on the clay--which is formed simultaneously. Accordingly, both the soluble and the adsorbed elements should be available to plants. This breakdown is rapid enough to do much toward restoring the fertility "while the soil is resting."

The second source of inorganic nourishment, listed above, is the major one for agricultural crops. There the ionic behaviors exhibit a relation of each element to each of the others within the suite of them. They seem to move into the plant root as if marching in a "company front" from the surface of the colloidal clay or humus. But that march is commanded by the hydrogen coming, in exchange, from the similar surface of the plant root--which is excreting carbon dioxide to give that active hydrogen, or acidity, in the resulting carbonic acid.

The third source of inorganic nourishment for our crops--namely: the delivery of inorganic elements, (a) as separations from the soil organic matter, and (b) as combinations with remnants of it--is not yet very widely appreciated, especially in this latter aspect. Increasing research is telling us about the soil organic matter serving as a liberator and as a carrier of the inorganic elements. The organic carrier compound is even entering the plant with them in the latter service.

Food availability

The liberations of nitrogen and sulfur out of their union within the organic matter for availability to plants has been worked out in what is the processes of nitrification and sulfofication respectively. But in connection with such a cycle--like that of nitrogen going from the soil into plant and animal nutrition and back to the soil organic matter again--there are apparently some secondary effects of an organic nature, still unknown, but significant for better or for worse. The quality of the proteins synthesized by plants according to nitrogen fertilization (or the excess of nitrates in plants) may well be connected with this consideration.



THE ROTATION OF NITROGEN IN NATURE

While the cycle of nitrogen in nature emphasizes its conversion from the poorly ionized states within organic combinations to the simpler, highly ionic, inorganic forms--to be be taken by plants or lost to percolating waters--that element may be going the plant for nutritional services there without being so active as an ion. This is suggested by chelation of inorganic -ions in which organic nitrogen seems to be very active as larger molecules.

More recently these vehicular services for the inorganic elements brought into the plants by the organic compounds of the soil, have brought this neglected fraction of the soil into decided prominence in plant nutrition. This service by the organic matter is called chelation. In that, the inorganic ion becomes inactive by combining with an organic compound of protein-like properties. But yet, by that combination into the large molecular complex moving into the plant root, there is more of the inorganic elements moved into the plant than when the soil offers that in its smaller, ionically active unit to the plant root.

* *Nash, V. E. and Marshall, C. E., "The Surface Reactions of Silicate Minerals:*
I. "The Reaction of Feldspar Surfaces with Acidic Solutions," Res. Bul. 613, Missouri Agri. Exp. Sta. 1956.
II. "The Reaction of Feldspar Surfaces with Salt Solutions," Res. Bul. 614, Missouri Agri. Exp. Sta. 1956.

(Continued in October)

Let's Live Magazine, October, 1960

DIFFERENT SOILS,
DIFFERENT PLANT COMPOSITIONS

Chemical Composition of Plants and The "Feeding Power" of Their Roots

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
Prof. Emeritus of Soils, College of Agriculture, University of Missouri, Columbia, Mo.

Part XV, continued from September

The service given inorganic elements by organic compounds of the soil, called *chelation,* is a prominent factor in plant nutrition. The inorganic ion becomes inactive by combining with an organic compound of protein-like properties. By that combination into the large molecular complex moving into the plant root, there is more of the inorganic elements moved into the plant than when the soil offers that in its smaller, ionically active unit to the plant root.

This service is especially unique in that the inorganic element and the chelator compound need not necessarily have been combined before they enter the root. It has been demonstrated, by means of the divided root system of the plant with the two parts in separate containers, that by offering the organic chelator in one container (or one part of the soil) and the inorganic ions in the other, the former is taken into the plant and serves to move more of the latter into the plant roots from the other container than when the plant grows without the added organic substance serving as the chelator.

Experimentation for proof

Laboratory compounds with this chelating property contain nitrogen in amino combinations of it, much as is found in proteins. It is suggested that the chelating, or non-ionizing, effect on the inorganic element results because of its combination with that amino, or protein part. Thus, the increase in the plant's content of the inorganic element occurs simultaneously with the increasing concentration of the plant's amino, or protein-like, nitrogen. This results in plants of higher nutritional values as forages for animal feeds.

By their higher concentrations of crude proteins, the plants increase their, power of feeding on the essential inorganic nutrient elements adsorbed on the clay. The roots of higher protein contents have an increased capacity to remove the adsorbed inorganic elements off the clay of the soils, or to take these off to a higher percentage of the total supply. This is a case of the plants being nourished by the soil organic matter as a means of feeding themselves more effectively on the inorganic, rather than vice versa as we commonly believe.

This fact was established experimentally at the Missouri Experiment Station through the research by Dr. Hampton, now of Texas. It was illustrated, also, in the Australian observation that sheep will exhibit the symptoms of cobalt and copper deficiencies when feeding on a pure stand of a non-legumenous grass (*Phalaris tuberosa*) grown on the Ninety-mile Plains. But if the protein-rich legume--namely, subterranean clover--is seeded and grown with that grass to only a small percentage in the feed, the sheep will be provided with enough of the trace elements in question to keep them healthy.

Decisive conclusions

These facts tell us that the soils are not necessarily deficient entirely in the inorganic trace elements. We are merely growing crops too low in protein and protein-like compounds to give them feeding power enough in their roots to take those essential inorganic elements from the soil. Also there is not enough of the protein-like organic matter maintained in the soil to serve as a chelating agent to move both the inorganic element and the chelating nitrogen into the crop. In either case, there is the emphasis on the importance of the quality of the soil organic matter by which the higher nutritional value of the crop as feed results at the same time that the crop's power of feeding itself on the inorganic fertility of the soil becomes greater. These facts suggest that the soil organic matter improves the chemical composition of the plants and increases the feeding powers of their roots.

(Continued in November)

Let's Live Magazine, November, 1960

DIFFERENT SOILS,
DIFFERENT PLANT COMPOSITIONS

Vegetable Quality Reveals Its Connection with Soil Organic Matter

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part XVI, continued from October

It has become a greenhouse practice to replace the soils in the benches after a few years of use. Yet, in nature, we view the soil's service in growing crops as a nearly perpetual one. Much has been said about maintaining our soils in a *permanent* fertility. In greenhouses without benches, where the earth floor is cultivated, the troubles--because of lowered productivity--also arise in a decade or two.

Where the more perennial crops are grown under glass, like the large purple grapes in Europe, the lifetime service of the soil is extended by planting the vines just inside the outer walls. The houses are small and narrow. The successful grape growers tell us, "The roots of the vines must get out of doors."

Productivity fails

When such soils under glass begin to fail in their productivity, moving of the house corrects the problem in a moderately humid climate. Closer study of the trouble proved that it was caused by the soils in glasshouses becoming salt-laden under (a) the limited watering (less than annual rainfall rates); (b) the higher temperatures; and (c) the generous applications of commercial salt fertilizers.

Nature did not accumulate the disturbing salts of sodium, potassium, magnesium, aluminum, sulfates, nitrates, bi-carbonates and others to prohibit crop growth on virgin soils in a moderately humid climate. Soil troubles in glasshouses in that climatic setting come *earlier,* as more soluble fertilizers are used. They come *later* as more organic manures are used in the fertility treatments. Dangers from soluble fertilizers applied in the fields with the seeding--which dangers are lessened by special fertilizer placement--increase as the soil's content of organic matter declines.

Scientific studies

Scientific studies are now beginning to uncover what suggests itself as the secret of the natural protection which the soil organic matter and the dense microbial population give to our crops against soil salts. Those crops of large yield and high quality are taking so much of *available* inorganic fertility elements from the soil that, if they were water soluble in the immediate root zone, they would suggest salt injury to the plants.

It is slowly dawning on us in agricultural practice that while we make (and recommend the use of) salt fertilizers--which are particularly high (a) in water solubility; (b) in ionization; and (c) in chemical activities--yet when those inorganic elements move into the first cell inside the root they are no longer in true solution, nor behaving as single ions. They have been united into the living, organic compounds to be no longer strictly inorganic and separated in their action as we have them in our thinking.

Secret

In that fact there lies part of the secret of high quality of vegetables. We do not take to very much of any kind of salt readily. Even for the wild animals, the "salt-lick" is an act of desperaion and not the law of nature when wildlife takes its medicine by choice of plant species or the same species chosen according to soil fertility growing it, and lot by going to the drug shelf.

For truly high quality in our vegetables, we must shift our concept away from the inorganic fertility as water soluble ions, and also away from them as an *ash complex* within the plant. We feed to view those inorganic elements as the potential creators of life, moving into the plant cells to become only a small part within a large organic complex.

Ionized elements

The highly ionized elements we have outside the plant roots are not the rule within the cells. There may be some ionized potassium in solution around, or outside of, the plant cell. In those large non-ionized complexes, the organic portion bears a ratio to the inorganic much the same as the combustible dry matter of the plant bears to its ash, namely 19 or 20 to 1. That makes the plant's ash compose but 5%. Only a small ash, or salt, content is required with all the inorganic elements in proper balance or quality in good plant growth and yields.

This concept of the use of the inorganic elements within the larger organo-complexes, as part of the living processes, suggests itself as also a prevailing function of the inorganic fertility in the microbial processes of the soil. It has been demonstrated as a means of moving more inorganic fertility and of the less soluble from the soil into the roots. It is a way by which the so-called *insoluble fertility becomes available* to microbes and plants. This has long been a natural process that seems to be revealing itself as a secret of nature, now that we have discovered a similar behavior in the laboratory which we call "chelation." Only slowly are we putting science under nature's secrets of growing better vegetation, when she is returning more of the organic matter back to the soil.

(Continued in December)

Let's Live Magazine, December, 1960

DIFFERENT SOILS, DIFFERENT PLANT COMPOSITIONS

"CHELATION"

Nature's Emphasis on Soil Organic Matter

by William A. Albrecht, B.A., B.S., M.S., Ph.D.
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Part XVII

When someone says, "I don't believe it!", it may be a confession of ignorance and not necessarily a denial of the fact.

That same contradictory remark, directed against the importance of the soil organic matter for growing vegetables of better quality, comes often from those who have never enjoyed, gastronomically, the doubted fact demonstrated by nature as an established truth. It comes even from some scientists and agronomists, who remind us that vegetables can be grown in water solutions of nothing but the simple inorganic elements commonly and naturally breaking out of rock minerals which give us our soils. They present that demonstration as if it were proof that organic matter (and clay) without water-soluble elements could not be helpful in growing crops. This is like saying that the fact that one can be nourished and live as a vegetarian denies the possibility of being nourished and living as an eater of meat--demonstrated by the polar explorer, Vilhjalmur Stefansson.

Unlocking a secret

A recent discovery in the chemical laboratory, spoken of as "chelation," suggests the secret of nature's chemistry using the organic combined with the inorganic matters in growing better crops, by emphasis on the former. This revelation should be helpful to those who do not like to accept practices of an art in nature without first comprehending the science under-girding or explanation.

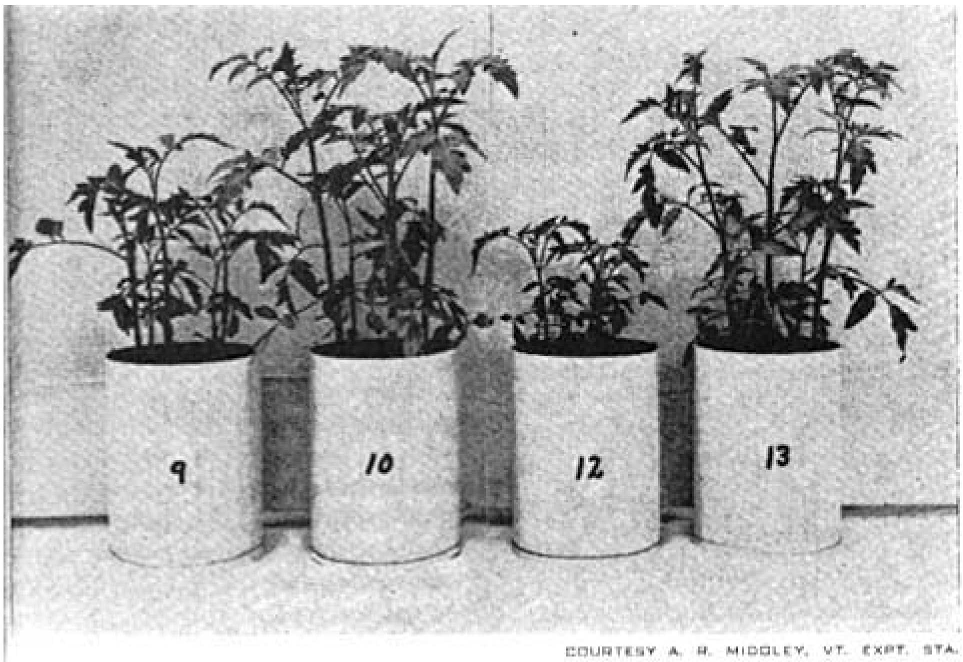
Chelation views the processes in the soil and in the plant for its growth without separating them into the inorganic and the organic kinds of chemistry, as we did in formulating our earlier concepts of soil fertility and plant nutrition. It gives a clearer concept of the small, highly active, inorganic elements in combination with organic molecules, many times larger, for the better nutritional services by the former as well as by the latter. This concept had long been suggested in the many observations coming from those practicing the organic art, but which the science had not yet formulated satisfactorily for itself.

Working elements

It is a widely recognized fact that phosphates, insoluble and soluble--and particularly the latter--are more effective in growing better crops when mixed with barnyard manure. Also, the combined soil treatments of ammonium salts and soluble phosphates mobilize more of the latter into the plants for better growth than when soluble phosphates only are applied. Sodium nitrate in the combination does not increase the mobilization. Calcium nitrate even reduces it.

The element nitrogen--the common symbol of the living compound, protein--is prominent in bringing about the chelation of calcium, iron, cobalt and many other elements, as examples. The nitrogen serves to connect the inorganic with the larger organic part of the final inorganic-organic complex that results from the chelation. This robs the chelated inorganic elements of their common property and chemical activity which we usually emphasize for them--namely, their solubility in water and their ionization, respectively.

This concept of chelation helps us to visualize the services by the soil microbes in their "take-up" of the salt-shock when ammonium phosphate, for example, is added to the compost heap; when those soluble, inorganic, nutrient elements are put into insoluble but much larger organic complexes; and when thereby both parts of that complex are made more available as nutrition to the plant roots.



PUTTING MANURE AND SOLUBLE PHOSPHATES separately into the upper three inches of soil (pot 9) was not as effective for best growth of tomato plants as was mixing the two fertilizers first for chelator effects and putting them into the soil (pot 10). Both treatments were less effective when mixed into six inches of soil (pots 12 and 13, respectively).

The laboratory-synthesized chelator, *ethylene-di-amine-tetmacetic-acid (E.D.T.A.)*--put into a soil of no iron content containing one-half of the root system and the other half in soil given iron in the presence of phosphates, thus making both less available according to solubilities--demonstrated that this chelator (E.D.T.A.) was taken by the roots from the first half of the soil. It served to mobilize the iron from the other half. It corrected the chlorosis which occurred under similar conditions, save that there was omitted the application of the special chelator. The use of water leachings from highly organic soils as substitute for the synthetic chelator (E.D.T.A.) served for effective iron mobilization just as the special compound did. Such facts suggest that very probably microbes and soil organic matter have been natural chelators at work for better plant growth during the past ages.

Simple samples

Such views of soil organic matter should not stretch our mental capacities too much when chlorophyl is a case of chelated magnesium. That complex is made up of one part of this inorganic matter in 40 parts total organic and performing the marvels of photosynthesis by plants. The magnesium is not ionized, but can be taken out by acids.

Also the hemoglobin in our blood is a chelated complex that has but one part of inorganic iron in 55 parts of organic items. In addition, vitamin B-12 has cobalt chelated in a corresponding wide ration. Yet this vitamin was discovered in the cow's droppings by chickens long before the chemist did, and long before he had the concept of chelation.

Perhaps in due time we shall appreciate nature's use of soil organic matter for growing higher quality into our vegetable foods. Let us hope that we can accept more widely the natural art of organic fertilization without the pressure from so-called "educational helps" in sales literature.