Let's Live Magazine, January, 1954

Amino Acids in Legumes According to Soil Fertility

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

Agriculture and gardening are concerned with the synthesis of food. Our ultimate goal in this has always been the increase of production, i.e. greater numbers and more pounds, per acre. Too often only such physical attributes of the products--even of people--are of prime consideration when some other criteria are of more fundamental importance. We neglect the quality of our food products and continue to measure our output only in bushels and tons per acre.

When the soil fertility declines, our attempts to adapt crops to a lower level of plant nutrition becomes a fallacy, that is, in terms of the demands of the human or animal diet. Of the many requirements of any diet, protein presents itself for first consideration. In the growth of any healthy animal, the major problem is this one of obtaining sufficient protein of the quality commensurate with good nutritional demands. Just as the furnace must be constructed prior to its service in consuming fuel, so must ill animals use proteins to build their bodies, prior to any consideration of their expenditure of energy.

Aminos first

In the animal the mere hanging on of fat is much of a luxury performance to which we have all wantonly subscribed. In agriculture we must become concerned with the biosynthesis of the building stones of the body, namely, the amino acids, making up the proteins; and not be content to adopt as our criterion the photosynthesis of the carbohydrates composing the plant bulk.

While this plant bulk may reflect other factors of the environment, we have been able to trace many of our nutritional problems to the effects of the ash constituents coming via the plant.

These soil-borne nutrients control plant metabolism more than we yet appreciate.

Biosynthesis

Biosynthesis requires these inorganic elements, not only to catalyze various reactions within the plant, but also to fashion and to build its structure. In turn, animals depend on the plants to synthesize the protein constituents for them. Herein lies the vital function of the soil. According as the different soils deliver divergent quantities of the inorganic elements, so we experience the pattern in the ecological array of the plant species. Each species represents a different organic composition according to the differences in the soil fertility.

Table

AMINO ACID CONTENT of ALFALFA HAY ACCORDING TO SOIL TREATMENTS WITH TRACE ELEMENTS (Percentage of Dry Leaves)

Plot No.	Treatment	Valine	Leucine	Arginine	Histi-dine	Threo-nine	Trypto-phane	Lycine	Isoleu-cine	Methio-nine
1	Calcium	2.19	4.37	0.380	0.654	0.862	0.546	1.57	2.64	0.100
2	Calcium and manganese	2.40	4.89	0.434	0.807	0.954	0.640	2.12	3.63	0.242
3	Calcium and boron	2.13	5.55	0.418	0.726	1.071	0.856	2.13	4.09	0.173
4	Calcium and mixture	2.59	5.24	0.415	0.835	1.014	0.670	1.87	3.44	0.229

In order to determine what fertility elements might be the cause of the diversities, alfalfa was grown on a single soil given treatments of the separate trace elements, manganese and boron, and a mixture of these with some others, as supplements to the common fertilizer elements calcium, phosphorus and potassium. Wide diversity in the amino acid array in the protein could scarcely be expected when relatively small amounts of these trace elements are applied on the surface of the soil. Yet the quality of the alfalfa protein in terms of its constituent amino acids was modified by these soil treatments, as shown in the accompanying table.

Diversity

While a marked diversity manifested itself in the case of each amino acid, the methionine content varied most widely of all the amino acids measured in this study.

Seemingly these results substantiate the hypothesis that these two trace elements--manganese and boron--function in the conversion of the carbohydrate into protein.

Let's Live Magazine, February, 1954

This article, "The Soil Fertility Pattern," was missing from the Library of Congress's holdings. It would be much appreciated if a patron of Soil and Health Library would investigate the holdings of their local library and if possible, supply a clean photocopy of this missing segment. The remainder of Albrecht's production in 1952 is available here.

Let's Live Magazine, March, 1954

The Little Things Count in Nutrition

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

We were startled a few years ago to discover that a little of a trace element, like manganese, missing in a chicken's ration would let the chicken go down on its hock joints, or its elbows, merely because the bones failed to develop the little stirrup-like growth through which a tendon must go and be held from slipping off.

What has manganese got to do with that trouble when we analyze the bone chemically and find little or no manganese there? It illustrates deficiency in our thinking that needs notice. We fail to realize that ash analyses are no complete index as to what we must provide by the way of the soil to make body construction complete. You can analyze the bone and find that the manganese isn't there in any significant amounts.

A tool

But the manganese was there and served as a tool somewhere along the line. Perhaps it shaped something or synthesized something that must come in to play if that chicken is to keep from going down with those slipped tendons. We must remember, that in these syntheses of all it takes to make a healthy body, many of these things that come from the soil are tools along the line and not products of the final construction.

You could analyze this building today and you would not find a single mason's hammer or trowel in it. Would that prove that the trowels were absent in all of the history of this building and that none are essential for buildings? They were here at a certain time, but now they are gone.

A longer time

The chemical analysis of this building will not give you the details by which you could construct another one in good order. Then, too, you wouldn't need 10 times as many trowels to build a building 10 times as big as this one. The same number of trowels that were in this building during construction will build a building 10 times as large, but it will take a little longer time.

Time is what nature takes to build or to break a body. So this matter of making a chemical analysis of a body and then interpreting it as a guide to build another one is entirely fallacious and insufficient. Yet many health practices are founded on conclusions no more logical.

Trace elements

By that token, we can talk about the trace elements. We don't know where they are in the body or where they function in all cases.

You don't think of trowels unless you see a building being built. You can analyze all of the buildings in the world and it will never dawn on you from that approach that you use trowels or levels or chalk lines or scaffolding. And it is in that same viewpoint--that there is much to he considered as coming from the soil as tools--that up to this moment we haven't considered as essential.

Nature's secret

Of course, we haven't really seen nature perform. Body growth isn't a morion picture flashing on the screen. It is nature's secret in many phases yet. If you started out to build a building and didn't have some trowels, you might have some deficiencies in that building. You might lay those rocks up some way or other without those tools, but sometime later the rocks would shake apart, and the building would fall and crash because there were defects that came in during the process of building that structure.

So, in the process of growth (quite more complicated than the process of hanging on fat), there are times when the deficiencies as small as those of the trace elements can become significant. Let's remind ourselves then, that in this problem of providing material for construction and the tools for erection of a body if we should have a shortage in any of those performances, or a low quality somewhere along the line, we must expect the final product to suffer accordingly.

Bad luck?

Too often when we have a manifestation of ill-health, we say that it is "bad luck." If, for example, you have a calf that is born in August, and the season goes into a droughty autumn so that the mother cow doesn't have very much to feed on, the cow can not give much to the calf. If it was a droughty summer while that calf was being nourished as a foetus, and both cow and calf go into winter dry feed until spring comes along, it ought not to be startling or surprising if in April that calf is down with some trouble suggestive that the femur bones had snapped at the hip joint.

We say, "We had bad luck--those calves did not go through the winter." Of course they didn't. What is the cause of the trouble? Is it the winter? Is it the cold weather? No, it is the poor nutritional level which that season has provided.

Let's Live Magazine, April, 1954

Animals Know Good Food!

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

Our farm animals are telling us much--but they speak in a foreign language. The situation reminds one of the fellow who said, "Money talks but so far as I am concerned, it speaks a foreign language."

The case of a famous Missouri donkey (or jack) reveals the story of the soil as the basis of animal production. This animal came from that part of Missouri where donkeys were made famous. The great breeder that used to breed them unfortunately isn't with us any more. The farm on which that donkey breeder made himself famous in Missouri was known as Limestone Valley Farm.

THE DESERT PROSPECTOR AND HIS PICTURESQUE OUTFIT . . . The diet of a burro, or donkey, is high in calcium and in alkaline earth elements. He is a most trusted saddle or pack animal because of his surefootedness.

Pedigree didn't count

We must not forget the donkey is native and wild in the regions of low rainfall, where there are high concentrations of calcium in the soil. He is an animal that is surefooted and accustomed to crawling from rock to rock. He is a most trusted saddle animal for you, if you want to go down into the Grand Canyon. The burro, or donkey, is given to a diet that is high in calcium and in those alkaline earth elements, because of the soils that grow his feed. Move him out of Missouri, or move him off the Limestone Valley Farm in south Missouri to northwestern Missouri where this one under discussion went as a colt--because he had a noble pedigree and sold for $5000 on the strength of that pedigree--and another severe case of rickets comes up, as this one did.

When this donkey was moved into that part of Missouri which we say is great blue grass land, his pedigree couldn't keep him free from this terrible affliction. The animal was deformed under that level of nutrition. In spite of all that could be done for him, a shift from one soil to another was more significant than breeders, veterinarians, and others dealing in animals ever surmise.

Selective instincts

Observations of choices fay animals at large, and under control, using feeds grown on soils given different treatments, point out the animal instincts for selecting not mainly carbohydrates for laying on of fat, but proteins, inorganics, etc., for body growth and reproduction.

Animal behaviors are now undergoing much closer observations. Reports of animal choices according to the soil are becoming numerous, and the various explanations of the causal relations are legion. As assayers, our animals are making excellent biochemical contributions. The animal's instinctive choices of its grazing according to the soil fertility, but its ingestion of almost any plant on fertile soil--irrespective of our classification of it as a weed or as a commonly accepted herbage--points out the animal's acceptance of crops according to the soil's synthetic services through them and not to the reputation founded purely on plant pedigree or scientific name.

Soil in control

Rabbits fed the same variety of hay from the major soils with and without treatments, in an area as extensive as the State of Missouri, demonstrated wide differences in growth, bone development, and body physiology according to the soils and their treatments. Originally as uniform as possible in breeding and selection, they were widely different for the various soils after a short feeding period. We are slow to see the soil in control of the characters of the animals, while we cling to a traditional faith in breeds and pedigrees as determiners of animal body form.

Deficiencies in nutrition are gradually coming into consideration as causes of poor health. However, it is at a slow rate at which those deficiencies are being considered as originating in the soil; either directly as a shortage of indispensable inorganic elements, or indirectly as compounds fabricated through their help in microbes, plants, and animals.

Trace element therapy

In order to test the hypothesis that such a baffling ailment like brucellosis in animals and man may be due to deficiencies, particularly of the trace elements in the soil, Ira Allison, M.D., Springfield, Missouri, volunteered to cooperate and try some trace element therapy on afflicted humans as was suggested by Francis M. Pottenger, Jr., M.D., of Monrovia, California. Dosages of manganese, copper, cobalt and zinc under enteric coating have been used on more than 1,000 brucellosis patients to date. Other ailments have also been included. The changes in the blood picture and other clinical aspects, coupled with the patients' reports of improvements in health, have been most encouraging with hope for relief from this disturbing ailment. This hope also includes amelioration of other ailments, like arthritis, allergies, anaemia, eczema, angina, etc., as possibilities.

We are slowly coming to believe that much that we now call "disease" should be more correctly labelled nutritional deficiency. As this is more widely granted, there is a growing appreciation of the importance of soil fertility in nutrition in general. Such recognition is making each of us more ready to take some responsibility in conserving the soil by which all of us want to be well fed and thereby healthy. It is also putting less emphasis on fighting disease and more emphasis on its prevention by better foods grown on better soils.

Let's Live Magazine, May, 1954

Agriculture is Biology First and Foremost

by William A. Albrecht, A.B., BS., M.S., Ph.D.
Chairman. Department of Soils, College of Agriculture. University of Missouri, Columbia, Mo.

In our research in the Department of Soils of the Missouri Experiment Station, we have labored for a number of years to work a combination so that we can get soil fertility and an plant nutrition linked together in a language which we all understand.

Those of us who are dealing with research projects in the Experiment Station are now thinking and planning for 10 years ahead about problems on which we ought to spend Station money in the future, assuming that we shall get some. We are trying to make sure that we give just rewards for the money invested in the materials and for our time in the work.

Broad scope

In opening this broader subject of soil fertility and plant nutrition we may well be reminded that it is much broader than what is commonly included under that title. It will eventually encompass more than any of the rest of us might now include.

AGRICULTURE
PRODUCTION IS LARGELY
NATURE'S PERFORMANCE
. . . Not a man-made science.

Much that is said about our scientific progress, in which we are about to believe that we have reached the pinnacle, deserves some rather critical examination. It seems that we are allowing ourselves to be so easily deceived by our success. There is a terrific danger in over-confidence. Even though we can fertilize the soil we are not quite yet controlling Nature at that point of her activities. The burden of the thought is in those few words, namely, we do not yet create crops.

Technical progress

We are delighted in the technical progress which we have built up and which raises our standard of living when you consider technologies. Technologies apply only, however, when we consider our control of dead matter. As for me, I am not quite ready to put agriculture in the class of the science under control, like a technology is, for example, when you look at the assembly line of an airplane or an automobile.

It is more nearly correct to talk about agriculture as an art, plus some science. It is not yet a case in which the science is in complete control. Agriculture is still an art, which we study by deduction, that is, we look at it as a natural behavior. We take a fragment out of it and put a little science into that portion. But when we take complete control we must have the science so well organized that we can put all the parts together and run the whole process from creation to death. Nobody as yet has been able to do that with agriculture.

Definition

Agriculture is biology first and foremost. It is technology and management second. We need only to remind ourselves of the last two seasons to be reminded how readily we use the weather as a scapegoat, when the crops didn't behave as we thought we would like to control them.

It is fitting, therefore, to provoke your thinking about the sciences applied to agriculture in a technological viewpoint only as a possible or even serious danger. Some of the agricultural troubles for which we are apologizing came about because we used technologies to upset the biology of agriculture. Much that is apt to be called agricultural science has upset the biology and we are coming now to reap the bad harvest.

Nature's performance

We are beginning to realize that the matter of agricultural production has been largely Nature's performance. Very often we have not had very much to do with it. We have been copying and memorizing agricultural practices, but have not been comprehending the basic principles that operate under Nature.

Let's Live Magazine, June, 1954

The Upset Biological Processes

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

We may well list several cases in which we have upset agricultural biology rather than helped it. We have been taught that crop rotations build up soil fertility. Yet, Nature uses continuous cropping and doesn't rotate the crops when she builds up soil fertility. We have upset the biology in that case very decidedly.

We are now trying to put a grass agriculture over much of the country where Nature had tree culture. Then we are going to let the cow make up the difference between our ignorance of quality grass and the cow's knowledge of it. We put the plow ahead of the cow. The cow is about to be extinguished if, as a matter of legal procedure, we follow the philosophy of killing cows to get rid of diseases like brucellosis, hoof and mouth disease, and others. How we ever got such a belief to prevail is strange; namely, that we can have cows when we keep killing them because we make them sick.

Primitive man

Primitive man lived on the dry lands. More recently in human history we began to farm those lands which have high rainfalls. Then, when rainfall goes back on us. we run to the Federal Treasury, as though that were the place where one gets any biological help.

As another upset of biology, instead of leaving plant residues on top of the soil, as Nature does, we bury them as deeply as we can.

Nature used different soils to make grasses on the prairies than she uses in making trees in the forest. Yet here are some folks who believe that the prairie grasses make prairie soils and the forest trees make forest soils.

Acid soils

Nature uses plant roots to make soils acid in order to get fertility into the plants. We want to put a carbonate in the soil so that the root cannot put its acid out any farther than barely off of itself. Yet plants nourish themselves by making soils acid. We fight the soil acidity by means of carbonate instead of feeding the plant with calcium and magnesium in the limestone.

Nature washes soluble fertility out of the soil into the sea. We make fertilizers soluble before we put them on the soil. If they remained there in that form they would soon be in the sea, too. Or, we mine the sea salts as soluble fertilizers, like potash salts, and put them through another round of going from the soil and into the sea.

Cattle and plains

We put cattle and grass into the plains where there are areas of ever-threatening drought and succeed, because that is where Nature had successfully put a similar beast, the bison. But we put them on the grass amongst the forest tree soils, under high rainfall, and then wonder why their reproduction is failing.

Nature doesn't have animals live to get fat. Experiments point out that our animals are searching for anything else but fattening feeds. They are searching for those which help them protect themselves against disease and encourage them in their reproduction. But, when we feed animals, we cut the amount of protein in their ration down to the limit, because we want to make cheap gains rather than to give the animals the help they need to be healthy and to multiply. Instead of letting the animal live long, we cut their life spans down to the most early maturity we possibly can, and then call it "cheap gains."

Manipulated economics

Some significant economic aspects might well be considered critically when manipulated economics have manipulated machinery, money and technologies into agriculture, but have almost manipulated biology out. Bankers are about to believe that we can substitute capital for land. Certainly all the capital in all the banks cannot substitute for the soil of the land. We know of no bank with all its money that could by means of that wealth have a litter of pigs, lay an egg, or give birth to a calf. And yet we have folks believing that one can manipulate biology by means of economics. You can't do that any more with money alone than you can with machinery and technology.

We have not yet understood, nor appreciated, agriculture as a collection of complex, but well-integrated, biological processes. We have not seen the soil as plant nutrition and thereby as animal and human nutrition, or the soil as the very foundation of all agriculture.

Let's Live Magazine, July 1954

Consider the Soil-- Not Technologies!

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

Because we turned away from much of the art of agriculture, we have serious confusion. Let us comprehend the fact that soil fertility, properly coupled with plant nutrition, is a form of creation--a form of outdoor biology--and is not a matter merely of scientific technology. We seem to have lost sight of the fact that the creative business of agriculture has always started in the soil.

In terms of wise fertilizer use the most shocking confusion prevails when we talk about soluble fertilizers--considering water as the agency for solution--and then we make laws requiring that fertilizers must be water-soluble and thereby so-called "available."

"Transpiration"

In fact and in Nature, these soluble fertilizers are never taken out of the soil, because the plant takes them into itself along with the water that it takes from the soil. The use of the major amount of water by the plant is that of keeping the respiring leaf tissues moist for the exchange of gases--carbon dioxide and oxygen. That escape of water from the leaf is called "transpiration." It is in that service that most of the absorbed water goes from the soil into the atmosphere.

The use of soil water is controlled by the meteorological situation, which invites water to evaporate from the leaves of the plants against the forces holding the water in the soil. The plant is an innocent connection between those two opposing forces that act on the water. Does the moisture in your breath move nutrients from your bloodstream into the tissues, or from your stomach into your bloodstream? Yet we take to the concept that the transpiration by the plant has something to do with the movement of nutrients from the clay of the soil into the roots.

Independent action

The transpiration stream of water from the soil, through the plant, and into the atmosphere is independent of the nutrient stream from the soil into the roots. The water uptake by the roots is the result of atmospheric conditions favoring evaporation from the leaves with a set of dynamics which are more than a match against the forces holding the water on the surfaces within the soil.

Nutrient intake by crops is a function of three colloids, or possibly four, in contact. First of all, there are the nutrients on the clay colloid, or on the organic colloid of the soil. The soil colloid is in contact with the root membrane, which is another colloid. That root membrane is in contact with the contents of a cell on the inside--namely, the protoplasm (or cytoplasm). In turn, that cell is in contact with another cell. In that you have the combination of the three or four colloids in contact. The movement of the nutrient ions from the clay into the root membrane and into the cells follows the chemical laws controlling their traverse there because of the differences in activities, adsorption capacities, interfering ions and other factors along that line.

Demonstration

Movement of nutrients into the root is independent of the transpiration of water. We have demonstrated transpiration going forward regularly--water moving from the soil through the plant to the atmosphere--when the nutrient ions were moving in the reverse direction--namely, going from the plant back to the soil. We have demonstrated the ions going into the plants regularly when there was no transpiration.

You can demonstrate this when you put a bell jar with atmosphere saturated with CO-2 and with water over the plant. You can stop the transpiration but you don't stop the ionic movement into the plant. Some recent work at the California Technological Institute shows that the desert plants put water back into the soil, while they are growing, therefore the water can be going back into the soil while the nutrients are going in the opposite direction. We must get rid of this water-soluble fertilizer bugaboo, in considering soil fertility and plant nutrition, because transpiration runs independently of our control. And we need to concentrate our efforts on keeping the stream of fertility flowing more regularly into the plants.

Matter of drought

Let us not cover either our ignorance or our responsibility in maintaining soil fertility by trying to blame the water situation in the soil and the rainfall. The idea that the "drought" is responsible for the failure of plant nutrition still persists. But what is commonly called "drought" isn't trouble in terms of water only. It is apt to be due to the fact that the upper layer of the soil--where the fertility is--dries and the roots must go down through a tight clay layer, which has almost no fertility. Then, because of crop failure in the absence of plant nutrition in that soil layer of stored water, we try to blame the drought or the bad weather. Drought may be merely a soil situation in which we have no soil fertility deep enough to feed the plants, when they are compelled to have their roots go deeper to get stored water.

Our contused thinking about drink for plants emphasizes the water facts as an alibi for our ignorance of plant nutrition and the soil fertility factor, where the emphasis properly belongs. During drought we don't use water to the best of our ability. We neglect to remind ourselves that the plant is about 95% air, water, and sunshine--and only about 5% fertility. We are too indifferent to that fact to consider carefully how we can use that 5% as the requirement to produce the other 95% of plant growth.

Our error

We blame the water. We blame the weather. The water of transpiration from the plants is like water going over the millwheel--only a part coming down the millstream. The amount of grist that one grinds in the mill is determined not so much by the amount of water that goes over the millwheel--the amount of which is fixed or limited--as by the diligence with which wheat is kept going into the millstones for 24 hours a day at full capacity. We haven't been keeping the soil fertility well and properly supplied to the crop plant; we are therefore in error when, for disturbed yields, we blame the drought.

Let's Live Magazine, August, 1954

Some Soils Analyzed

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

The problem of relating soil fertility to a plant's nutrition, as well as to its drink, was put under study here at the Missouri Experiment Station many years ago.

It seems fitting to review the history of the mental procedures by which we attacked this problem of adequate soil fertility and its services in the growth of plants--at least in terms of this soil aspect when others were adequate to the best of our knowledge.

Problem analyzed

Many years ago we made a kind of problem analysis. Division of the problem into its parts divided it according to the soil texture--namely, the sand, the silt, and the clay. We decided on clay as the part of the soil to study first. That choice was expectable because in Missouri we have almost four million acres of claypan soils.

About those it was commonly said, "Oh, they will make only about 20-30 bushels to the acre. Your crops drown out in the spring and you dry out in the summer. The Putnam claypan soil is a nice silt loam. It has a level topography and it would be fine but it just doesn't deliver by production. Farmers on it have some silly ideas and ways about handling it. They 'bar' off the corn in the spring, as they say, and then they 'hill it up' in the summer. It is a terribly acid or sour soil. You can't grow legumes on it. You can't build up its nitrogen."

Good by contrast

Yet, in spite of all the kind and unkind things said about this silt loam as a claypan soil, it is still a good one in contrast to the 10½ million acres of stony land we have in Missouri.

As an outcome we picked first on this Putnam silt loam and worked on its clay until now that clay is known all over the world by its technical name, Putnam clay. This basic research in the laboratory, in the greenhouse, and later in the field, has moved this soil into the corn growers' contests for the winning high yields per acre.

Sandy soils

Let us follow with the next and inquire, "What is in sand as fertility for plant nutrition?"

You may well reply, "It is largely quartz, it contains only silicon and oxygen. Those mineral grains do not weather down."

That is the reason the quartz crystals are still big grains. It never has weathered. It is a kind of soil skeleton. "Consequently, for the time being," we said, "let's throw that soil out of our mind and concentrate on the silt."

Silt considered

It also can be quartz. But then too it can be other-than-quartz. Its composition depends on the place where it is. The farther east one goes in the United States, and to the higher rainfalls, the more quartz there is in the silt of the soil. Silt doesn't have much capacity to hold fertilizer--neither does sand.

Because of their large particle size, these two have little capacity to absorb and to exchange nutrients to plants. But yet there is much silt blown in here from the floodplains of the Missouri River and from the west. It piles up along the river bluffs to give what is fairly good soil.

Soils catalogued

Thus the soils were catalogued for their order of importance for research attention. The silt fraction was set aside for later study when the initial study took to the clay soil.

We began with the claypan soil and its high content of clay since almost everybody wanted to enlist himself in what might be a fight with that tight clay. The early researchers bought and used much dynamite on it. They dug ditches of various kinds in it. They pushed it around with powerful machines. About the time they would have the treatment complete, the soil was behaving just about the way it was before.

Whether fortunately or unfortunately this clay has little or nothing inside of its crystal form of significant fertility contribution.

Small amount of iron

In some of the early work we did with it in the laboratory, we tried bubbling carbon dioxide through it only to discover that if you really treated it long and hard with carbonic acid you could break out of it no more than about the iron that would be required to grow a crop.

You might get a little magnesium out of it, too. But as a contributor of fertility we might credit it with iron, and one would be generous in doing that. From those early studies and the light they shed on the importance of the clay, there developed the research studies at this Station leading to our better understanding of soil fertility and plant nutrition.

Let's Live Magazine, September, 1954

The Role of Clay in Plant Nutrition

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

But what about the organic matter as a colloid similar to clay?" you might well ask. We found in our experiments some organic matter in the clay. About 1½ % carbon and about 15-hundredths of a per cent of nitrogen are found in our Missouri clay. They are still very tightly linked into the clay molecule even after you have oxidized the clay with hydrogen peroxide, and after electrodialysis to take out everything that you possibly can. These clay studies brought carbon and nitrogen in a ratio of 10:1 right in the colloidal clay itself. That is the carbon-nitrogen ratio commonly given for well-weathered soils. These organic elements seem to be a highly fixed part of the clay.

Because of these discoveries the clay had much later research consideration. We dispersed it in water. The larger particles were settled out, the coarsest clay was thrown out of the supernatant water by centrifuging. The remaining opalescent suspension was then electrodialized and the intense study of this clay began. It was on the basis of that attack and our increasing knowledge resulting therefrom that we are bold enough to talk about soil fertility and plant nutrition.

Plant chemistry

Because we have studied clay chemistry now for a long time we have moved to study plant chemistry in combination with that clay.

In his first experience of bringing colloidal clay chemistry into combination with the biochemistry of the plant. Dr. Hans Jenny met with disappointment in the plants so often that he was about to give up. But when near complete disgust with our theories, he finally caught the vision that the clay might be the dynamic center of the soil. He had thrown out two or three sets of plants before we rescued the situation. He had demonstrated the fact that it is a hard task to load the clay with enough fertility to feed a crop for its good health and growth. Subsequent trials demonstrated very clearly that the clay was the major center of the chemical dynamics in the soil which deal with the speedy process we might envision when we talk about growing a plant.

Season's supply

It was also discovered that the clay holds nearly the season's supply of plant nutrients, ready and exchangeable, for the root when it comes along. We have in the silt of the soil some of the reserve fertility that can be broken out when we consider that the soil is "resting." Research found that the clay within the plant root zone must hold approximately a season's supply of fertility. That supply can be increased by adsorbing more nutrients on the clay or by adding more clay. It is this factor that determines different fertilizer use on soils of different textures.

One can put a tremendous amount of fertilizer on a heavy clay soil and not see much difference, but yet the plants will register it pronouncedly. And that fact holds true whether you are considering fertilizers of nitrogen, phosphorus and potassium, or in the form of magnesium and calcium as limestone.

Root zone

The fertility held within the root zone is not leachable by water. It is not in the free water of the soil, and is, therefore, not in the water-soluble condition when it moves to nourish the plant.

We make fertilizers soluble so they will be speedily adsorbed on the clay, rather than held in water and be sucked in with the water by the plant. We have learned from these clay studies that calcium is major nutrient for most any crop we grow.

Our agricultural soils in general have less calcium when they are more acid (that is, they have more hydrogen); conversely, then, as they have more calcium they have less hydrogen.

Fertility deficiency

This simple nutritional situation of the importance of calcium--and the way the soil behaves under acidity as mainly a calcium deficiency--has kept us in ignorance about what soil acidity really is: namely, a fertility deficiency rather than a bad environment.

The roots make the clay more acid when the plants grow, because the hydrogen from the root and the calcium from the clay are exchanging places. The legumes are taking tremendous amounts of calcium off the clay.

Calcium saturation

It was discovered that the degree of the calcium saturation on the clay determined whether the nutrients moved from the soil into the plant root, or vice versa.

The clay, then, is the seat of all these activities: First, there is the absorption of the nutrients from any solution. That activity is involved in our use of soluble fertilizers. Acceptance of hydrogen from the plant root by the clay, and the exchange from the clay to the plant root are the major clay activities. The clay also is the seat of the breakdown of the reserve silt minerals, as this decomposition serves to restock the clay, especially noticeable while the soils are commonly said to be "resting." These are some of the basic facts about the soil's clay factor as it plays a significant role in plant nutrition.

Let's Live Magazine, October, 1954

Root Bio-Chemistry
And Clay Chemistry

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

We need to remind ourselves that the plant is carrying on a biochemical operation. It is not merely standing outdoors without being very definitely influenced by the soil.

We discovered that when the same amount of fertility was adsorbed on less clay or the clay given a higher degree of saturation, the plant root in contact with that clay experienced an increasing efficiency with which that fertility moved into it and into the crop.

Basis

In that simple fact there is the basis for the practice of banding the fertilizer application in the soil in place of mixing it throughout a large soil volume. In limited soil volumes, saturated with fertility rather than having it distributed all through the soils to have the clay as a competitor colloid against your plant root, is the basis for the efficiency in applying fertilizer in bands. The plant root finds the soil areas where it feeds itself to advantage.

Clay has always been serving to remove a good deal of the fertilizer hastily from solution by absorbing it and thus getting rid of the dangerous salt effects, which the plants always suffered when we drilled fertilizer, with the exception of superphosphate, along with the seeding.

Calcium salts

But as long as we used ordinary superphosphate or others containing a large amount of calcium, we could drill much more fertilizer with the seeding than one could without it. If potassium salts, or sodium salts were used with the seed, its germination and emergence were quickly disturbed. However, when plenty of calcium salts were mixed with them, then there was safety. Gypsum was that safety factor, often without our recognition of that saving service, to the plant's biochemical activities in the soil.

There is another interesting and significant fact we learned in our experiments. We could study one ion and vary it on the clay to get a certain behavior--with increasing saturation of the clay by that ion, provided the accompanying ions adsorbed on the clay behave differently even when the amounts exchangeable are constant; that they are held with different forces; that they move off variable into the atmosphere of their colloid: and that they exhibit different effects and different energies.

Organic matter

While using fertilizers and trying to explain the effects, the organic matter in the soil has been the saving grace for the plants in many cases. A low degree of saturation of the clay by the inorganic ions in the less fertile soils may be improved decidedly when we get more organic matter into those soils. When we put organic matter back into the soil we upset this more commonly considered set of inorganic chemo-dynamics of the soil, which must have initially dominated there. With less organic matter in the soil, we have a different rate of fertility deliveries and a rearrangement of the suite of ions on the clay. Organic matter, then, shifts the ration of the crop about very decidedly.

Considering the plant root as a factor in modifying soil fertility in plant nutrition, we have found that if the root was a protein-rich one, it exhausted the inorganic fertility of the soil to a higher degree than any non-protein root.

Legumes

In other words, a legume is the quickest way we can take the inorganic fertility off the clay and deplete its fertility to a lower level than we can by any other crop. One might well raise the point whether legumes have been soil-improvers. It suggests that we never really knew (we just had a kind of blind faith) that the growing of legumes improved the soil.

We know now from laboratory research and from field records that legumes can take the fertility out of the soil faster than the non-legumes.

The question may well be asked: "Shall we go back to that plot and try to build up its fertility by seeding legumes, or shall we study the sciences of the soil and plant nutrition to work with the biology the best we can by applied nitrogen and other fertilizers?" With present high costs of production and high taxes, what solution have we for some of these problems except higher yields per acre via fertilizers for economy of production?

Let's Live Magazine, November, 1954

The Sustaining Fertility of the Soil

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

If the soil fertility is to function efficiently in plant nutrition. we must give attention to the physiological requirements of the crop we expect to grow.

Do we know the proper ratios of the inorganic nutrients that ought to be moving off that clay into the plant root? As yet we do not, but researches are giving suggestions. By means of colloidal clay we are trying to work out a concept of a balanced ration of calcium, magnesium, potassium, etc., on that clay, possibly for each different crop--because different crops are synthesizing different organic compounds.

We know that the legumes require more of the different elements than are required by the non-legumes. Legume tops and roots are running a bigger factory. They are creating collections of different proteins about which we don't know much. What do we know about the plant's nutrient needs during the different phases of the growing season? While all of the different phases of this problem are confronting us, our declining fertility is slipping down faster and the problem is becoming much larger.

Clay research

The research on the clay at the Missouri Experiment Station suggests that restocking the clay, after exhaustion of its fertility supply by cropping, resulted from mineral breakdown in the silt fraction.

After we have studied the clay so much we are now studying the silt as a mineral reserve for crop nourishment. This separate is of more service in areas of low rainfall and less of soil development in the West than it is in the high rainfalls of the East.

Probably the silt breakdown in many of the mid-western soils and in others on coming east farther, has been the major supply of fertility. Therefore, our crop production is a weathering agent for soil minerals.

Restocking clay

Dr. E. R. Graham has done some very clever work to show that we can use these reserve minerals in contact with the dynamic clay, and thus restock the clay. That is what limestone has been doing when we use it on the soil. That is what rock phosphate does, too. When we have the Missouri River hauling lots of unweathered silt in from the West; with rather dry winters; and with the wind blowing that unweathered silt out of the river bottom and depositing about a 1000 pounds per acre of Missouri soil every year, it would seem to be good agricultural foresight to think about this reserve material as a fertilizer which Nature is giving us very generously each year.

This silt fraction, composed as it is of minerals other-than-quartz should bring all of us to consider more seriously the sustaining fertility in the soil. While we have learned much about soils, we scarcely have knowledge enough to maintain production by starter fertilizers only, particularly when we put them at the top of the soil--where that is dried out during most of the time--and then blame the drought for the failure of the fertilizers in doing what some folks commonly expect of them.

Organic matter

The most neglected and most important chemo-dynamic factor of the soil is the organic matter. Organic matter may be said to be the "constitution' of the soil. As for a definition of the word "constitution" in that usage, we take its meaning when the doctor consoles the friends of a patient in serious illness by reminding them that the patient has a good constitution. According to its meaning as used in medical practice, a good constitution is the capacity of the individual to survive in spite of the doctors rather than because of them. The organic matter in the soil has been the capacity for our soils and our crops to survive in spite of the soil doctors rather than because of them.

There is the tremendous significance of the organic matter as a season's release of plant nutrition. This release is timed to increase during the growing season, or become larger as the temperature goes higher. The microbial activities follow Vant Hoff's Law and double their rate of decay of the organic residues with every 10° rise in Centigrade temperature.

Most reliable

Nature has always been fertilizing with the organic matter which is dropped back to the soil from the previous plant generations which have died in place. Organic matter is still the most reliable fertilizer in terms of the nutrient ratios and of the time when maximums must be delivered.

Let's Live Magazine, December, 1954

The Importance of Soil Economics

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

Another aspect of organic matter about which we probably haven't thought much is the value of some organic compounds in cycle. That is, they may be dropped back as crop residues and the next crop's roots may be taking them up, using them and dropping them back again.

Plants need the various ring compounds in very small amounts to make some of the essential amino acids. They need the phenol ring in phenylalanine, one of the essential amino acids, essential for plant growth as well as for animals and ourselves. They need the indole ring, which is a phenal ring plus a side ring. It is the compound which gives the odor to feces when the digestion acts on the tryptophane of which that ring is a part. Tryptophane is the most commonly deficient amino acid, and is one of marked complexity.

Geared together

Then there are also the sulfur compounds and the sulfur-containing amino acids. We might well wonder whether man and his flocks have not been geared together so closely in their past history because some of those excreted organic compounds were put back into the soil, and were going through the cycle over and over again as a help in the survival of both man and beast. Now we are trying to divorce ourselves from animals, but perhaps we haven't found the basis of safety for it.

Organic matter must find a new and more important place in our minds as the neglected half of plant nutrition and soil fertility. In terms of the inorganic half of that responsibility we have partly understood about one-half of that phase, namely, the major cations. We don't know much yet about the cations of the trace elements. When it comes to those major inorganic ions--which are cations--we have a good concept of their chemo-dynamics for plant nutrition.

Much to learn

As for the anions like sulfates, nitrates, carbonates, and others, we do not yet know how they are handled by the microbes and the plant roots in the soil. We have much yet to learn when we have scarcely one-fourth of the field of soil fertility interpreted in terms of the basic principles of absorption, exchange, solubility, and what have you, when it comes to the problem of soil fertility and plant nutrition.

There is enormous opportunity for a big research program ahead. However, we have charted our course now and believe we have analyzed the problems, though by no means outlined the solutions for all of them.

Help needed

We need help from observing and thinking minds to take these concepts about soil fertility and plant nutrition out into the fields for test, whether our concepts are on the right or the wrong track.

Those who supply fertilizers have not discharged their responsibility completely when a carload of fertilizer has been delivered on the farm. They have the responsibility of making those goods serve properly in crop nutrition. Fertilizers must serve not just for increasing the crop bulk, but in terms of the necessary chemo-dynamics of soil fertility and plant nutrition which mean better nutrition for animals and man as well.

Economics involved

Our concern about soil fertility and plant nutrition naturally emphasizes their biological aspects. But even under demand for more food and need for a national agricultural policy, one dare not disregard some of the economics involved.

Unfortunately, agriculture uses soil fertility as its biological capital. To date such capital is still an unknown in the money marts, the bankers' vaults, and the political areas. According to present economics applied to agriculture, soil fertility capital is thrown into the bargain when we make a sale of agricultural products. Such values are not interpreted in dollars. The depletion of soil fertility, that is, the foundation for real food values, is not yet considered. Consequently the agricultural business does not have an accounting system for taxes on income, on lands, etc., set up to include fertility depletion allowances, allowed labor income, guarantees of perpetuity of capital assets, etc., to make agriculture, and the soil under it, self-perpetuating. Soil exploitation and land ruin with time are therefore inevitable.

No alternative

In spite of this lop-sided kind of economics for agriculture, when economics look toward guaranteeing self-perpetuation for most other forms of making one's livelihood--ven for the laborer by means of strikes--we expect increasing food delivery from the soil. There is no economic alternative except that the soil must be mined.

That must be the result if food production by agriculture is to continue and to increase under the present economic disregard of fertility as the factor giving real value to the acres of land. No national agricultural policy for survival under high standards of living can come forth unless we finally realize that our national strength lies in the fertility of the soil and our future survival in the wise management and utmost conservation of it.