

Fertilizer's Service In Plant Nutrition

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Perhaps the title for this discussion would seem more dynamic if we said, "Fertilizer Serves in Plant Nutrition." Whatever wording is chosen, that title should remind us that any fertilizers applied to the soil must give the most complete services in the nutrition of our farm crops if the business of manufacturing, distributing, and selling those commodities which we label "Fertilizers", is to hold a respectable and reliable position in the commercial and agricultural worlds. The fertilizer business cannot long survive by dumping any kind of chemical compound on the farmer's receiving dock in the name of "plant foods." It must service its goods all the way through the manufacture, through the sale, through the soil, through the crops, and even through to the nutrition of the ultimate consumer of the crop products. We propose here, then, not to review processes in fertilizer production, but rather to turn our attention toward the chemo-dynamics of the soil, and toward the physiology of the crop plants. By turning more concern in that direction, the fertilizers will not only sell better but will give a better service in the nutrition of plants, animals, and man in the fullest meaning of that term.

"NUTRITION VIA PLENTY AND COMPLETE (NOT CRUDE) PROTEINS" MAY WELL BE A SLOGAN FOR AGRICULTURE AND ALL OF US.

Fertilizers are a help in the better management of our soils for more efficient crop production. However, while we manage soils and crops for larger monetary returns, we must also manage them for better nutrition, better health, and better multiplication of our soil microbes, our plants, our animals, and ourselves. We nourish our plants while aiming for more vegetative bulk or more bushels. We nourish our animals while hoping for more gain in weight, much of which is water and fat. We nourish ourselves with ever-impending danger of excessive body fat and the degenerative diseases. Such is the low quality of our nourishment from many soils because of the absence of the fuller appreciation of the basic fact that the nutrition of all life forms is dependent on the fertility of the soil.

When food and feed are now accorded increased attention because of the mounting human population, but under declining combined populations of sheep, pigs, and cattle, why should we not turn our soil-improving efforts via fertilizers, and all else, toward the production of more proteins? Now that the delivery of carbohydrate bulk for filling and fattening has become a disappointing criterion for our agricultural efforts in production—and in maintaining healthy animals and people—isn't it high time to direct our aims in production toward growing more proteins? Should this not be the aim when these widely deficient food components, especially in their complete array of the essential amino acids, represent, (a) **growth** in terms of cell multiplication (not just water-logging and fattening); (b) **protection** against "diseases", i.e. invasions by foreign proteins; and (c) fecund **reproduction** for maintenance of the species? In our use of fertilizers, then, we must focus attention on making those soil treat-

ments connect the soil more specifically with the most complete plant and animal nutrition in which the soils and fertilizers can possibly function. Under this as a newer criterion for the services by fertilizers, the industry centered around these commodities will render a larger service for others and itself by assuming the responsibilities of studying nutrition in its broadest sense. Nutrition must be studied not only in terms of carbohydrates and calories, but also in terms of proteins and their fullest significance for **growth, protection, and reproduction** of microbes, plants, animals, and man, or for the entire biotic pyramid of which the fertility of the soil is the foundation.

Fertilizers and their functions in the soil will be better managed when many basic facts about soils, the chemo-dynamics there in terms of their secondary as well as their primary nutrient elements, their mineral reserves, the synthetic food services by crops, and the whole ecological pattern of all life in relation to the climatic-fertility pattern of our country, for example, are more clearly comprehended. Fertilizers will be better understood and more wisely used, also when some mistaken concepts are eliminated, and when practices in soil management are founded on what is truly soil science. Only critical research will weed out the erroneous practices rapidly and put our agricultural survival on higher security.

SOME BASIC FACTS OF SOIL SCIENCE CONNECTING FERTILIZERS AND SOILS WITH BETTER NUTRITION

Let us list and outline herewith, rather than discuss in detail, some of the basic facts connecting the nutrition of all forms of life closely with the soil, more particularly via the proteins which are becoming more costly as the fertility of our soils declines.

I

Our national fertility pattern resulting from our climatic pattern gives corresponding pattern to crops, livestock, nutrition, health and other aspects of all life whereby it puts the soil in control. The varied concentration of farms in the different regions of the United States outlines the varying chemo-dynamics of the soil for nutrition in a pattern duplicated, for example, by that of the radio efficiency. There are more farms in the same areas where there is the better radio service. When it is the fertility salts of the soil that are both the soil's conduction of electricity and the soil's production of crops, shall we not see the variable chemo-dynamics of the elements of soil fertility responsible for both the better crops, and the better radio transmission, to say little about the better physiological settings for higher forms of life?

The national patterns of these activities in farming and radio efficiency are determined by the pattern of the climatic forces (rainfall and temperature) they have been decomposing the soil minerals and keeping the stream of nourishment flowing to give us our feeds and foods of higher protein values for better maintenance of all life. Shall we not connect the soil more directly with nutrition as we study and come to appreciate these larger national patterns?

II

Plant nutrient elements and compounds adsorbed on and exchangeable from the soil colloids—and not necessarily in aqueous solution—are the fertility “available” to the plant roots. The clays, i.e., the colloidal fraction of the soil, are the seat of these chemo-dynamics. The nutrient elements are adsorbed there from the solutions of fertilizers, for example. They are moved from there to the plant roots. Such elements in their soluble forms do not move into the plant root along with the water necessarily because the fertilizer salts containing them are soluble, or so-called “available.” Water movement into the root follows one set of laws; nutrient movement there follows another set.

When the clay fraction—a negatively charged colloid—is highly stocked with adsorbed fertility elements, then the soil is nearly neutral in reaction, or it is not very acid. More acidity in a soil means merely less fertility per unit of colloid. **Increasing acidity in our natural soil is, therefore, simply decreasing fertility.** The presence of the hydrogen is not the detriment. Instead some hydrogen, or some acidity, is a benefit in connection with fertility. It “mobilizes” the nutrient cations. It will help the acid clays in their “processing” of the reserve minerals to make them become more “available.” It helps some soils to “recuperate” when we “give them a rest.”

The acidity, or hydrogen, resulting from the respiration of the root, exchanges itself to the clay for other cations, i.e., positively-charged ions, of nutrient service to the plants. The acid on the clay breaks down the reserve minerals to move more nutrient ions from them to the clay and from it on to the roots. Acidity, then is the chemo-dynamic power within the soil (but of sunshine origin above the soil) to keep the fertility assembly line of agricultural production running for full output. It does not run because of the water soluble fertilizers there.

III

Measuring the soil's exchange capacity and the stock of adsorbed nutrients in it gives more logical concepts of soil fertility and plant nutrition from it. More clay, i.e., more colloids, in our “heavier” soils gives them more adsorption capacity and more exchange capacity. Thereby it gives the more potential productivity. More clay means more fertility even if in company with a high degree of acidity, hence good plant nutrition is offered on “heavy” soils in spite of low pH values. Our “fight” on soil acidity has been a “blind alley.” Our use of gadgets to measure acidity and our devotion to the gadgetry has delayed the realization of the failing plant nutrition brought about by the serious fertility deficiencies. Our concern about soil alkalinity will probably find some relief when we study it under a concern about fertility shortage for the crop rather than a dangerous degree of alkaline reaction, as the chemist—not the plant root—views it.

Organic molecules, as additional cations adsorbed on the clay and as possible carriers of some anions, are a neglected corridor of our soil fertility researches. Organic matter suggests itself of major import in the case of the so-called “alkaline soils,” in the arid regions. In the humid regions, soil acidity has, fortunately, been connected with troubles in growing legumes, though not in terms of interpreting soil as nutrition for these protein producers. Clay must be recognized as the major soil separate on, and around, which the activities of the nutrient ions are centered. Silt can provide the reserve nutrient elements to be liberated by the processing of this soil separate by the acid clay. Sand as quartz grains must remain of skeletal service only.

IV

The adsorbed nutrients and their interactions relative to entrance into the plant roots are research areas offering much in better management of plant nutrition. The suite of ions adsorbed on the clay may be considered (a) the stock of fertility to be measured as amounts exchangeable, and (b) the collected activities of the many ions to be interpreted in terms of each ion in relation to “the company it keeps” rather than to the amounts exchangeable. It is the measurement of the “activities” of the ions that becomes significant in determining the amounts of nutrients moving into the plant or to be “absorbed” by the plant, as we say it in common language. This fact is suggested by the common emphasis on the many significant “ratios” of the ions “taken” from the soil by plants, and found in the plants according to the chemical analysis of them. The plant is at the mercy of the chemo-dynamics of the soil more than vice versa.

V

Research in soil fertility and plant nutrition needs to consider more than only some inorganic aspects of the soil-root chemo-dynamics in relation to soil treatments and composition of plants. One-half of the field of soil and nutrition might be considered as neglected in our failure to study the organic compounds which the plant roots may be taking from the soil for nutritional services. To date, we have been studying only the inorganic elements which plants take from there. Only the results of “ashing” the plants have been connected with soil as plant nutrition. We have not considered seriously the plants necessity to synthesize carbohydrates as truly “plant food” for the plant's struggle to synthesize from those carbohydrates the proteins, i.e., the necessary amino acids required for the plant's own nutrition if it is to survive. When tryptophane and methionine are amino acids synthesized by plants, then this performance is not merely a philanthropic service by plants to save our costs of purchased protein supplements for fattening livestock. Shall we not fertilize, then, with the hope of producing complete proteins for the nutrition of the crops we grow and thereby study the protein deficiencies for the crop's nutritions?

Another portion of the study of soil and nutrition, even in the inorganic phase, is neglected. To date the “solubility” of anions in an extracting reagent is our criterion of anionic behaviors in the soil. We cannot yet measure the exchangeability and the “activities” of the anions as we measure those of the cations in the soil. We have not yet considered the necessary suite of anions. When carbonic acid from the plant root, or the microbe, provides the bicarbonate anion to exchange for other anions, it is necessary that we develop our concept of how this less active anion can exchange for nitrate, chloride, sulfate, phosphate, silicate, and others of negative charge and of more active behaviors in the soil. The concepts of adsorption and exchange of anions held in the soil still remain to be developed. This half of the inorganic of soil and plant nutrition has not yet been painted in detail.

Perhaps it will not be too disturbing to remind ourselves of the fact that the generous stock of organic matter in our virgin soils has been a tremendous factor favoring our past successes from fertilizing soils with wholly inorganic substances. Much that is still unknown about plant nutrition may have been cared for by the soil organic matter, namely, that residue of the many dead generations of plants gone before. Soil organic matter may have been the “constitution” of our soils as we might call it, should we put a definition into the mouth of the

doctor of soils duplicating that inferred by the medical doctor of his human patients when he says "That patient has a good constitution." By that remark he may be pointing to the capacity of the patient to survive in spite of the doctor's treatments rather than because of them. Now that many of our soils have had their organic matter—their constitutions—burned out, the soil doctor's treatments will have smaller factors of safety. Soils of even the more northern latitudes are operating under shrinkage of the values of this safety factor. Only slowly are we turning part of the light—now so strong on inorganic fertilizers—over to those of organic nature.

VI

Any ecological array represents the placement of different forms of life on the soil growing, protecting and reproducing each most fully for survival. The climatic pattern of the development of the different soils for nutrition in fullest order has too long been viewed only in terms of water for plant use. Ecologists have too long tried to make the water the major factor controlling the distribution pattern of the species. The climatic pattern of the effects by rainfall in conjunction with those by temperature is more significant in terms of the resulting climatic soil fertility pattern which controls the ecological array of plants than it is in terms of water alone. This soil fertility pattern, that is, the pattern of plant nutrition, gives location to either carbohydrate-producing plants only or those producing proteins too, and those more complete in the delivery of all the essential amino acids required for the nutrition of animals and man. It is a climatic pattern in relation to protein production, more than in relation to any other major factor in nutrition in general. Protein production, i.e., the availability of the complete proteins for nutrition, is the major ecological factor controlling any life form.

The ratios of the calcium to potassium, for example, and of other elements to each other, control the synthetic services by the crops. The high ratio of calcium to other elements in connection with legume growth is not a matter of calcium as ammunition in the "fight" on soil acidity. Instead, it is a matter of the generous amount of calcium in connection with any of the crops given to the synthesis of much protein. The more generous amounts of it are required by plants carrying on nitrogen fixation from the atmosphere for good nutrition. According as the climatic forces of the weathering of the soils shift the ratios of the activities of the nutrient elements adsorbed on the clay, so there may be expected to be a shift in the carbohydrate—protein ratios in the plant's composition. A high degree of calcium saturation of the soil's colloidal complex is a requirement for higher protein concentrations in the crops. In considering the fertility requirements to improve our soils, then, the broader basic climatic pattern, giving different degrees of soil development or varying saturations of the colloidal clay as varying suites of ions, is a most helpful guide to the necessary fertilizers for efficient plant nutrition.

The larger ecological pattern tells us that managed plant nutrition must consider well balanced soil fertility for synthesis of protein within the plants to grow the crop. This is the parallel of nutrition of animals calling for attention to rations balanced in proteins to grow rather than only to fatten them.

VII

Accurate diagnosis of, and supplying, the fertilizer needs of the soils, not just sales, has become a new responsibility of the fertilizer industry. Fertilizer use has become a

matter of prescriptions determined by chemical facts (a) about the soil, and (b) about the physiology of the intended crop. It is becoming more and more a problem of providing larger amounts of materials as "sustaining fertility" as well as amounts of standardized "starter fertilizers" per acre limited so as to prevent salt injury to the seedling plants. Soil tests are becoming more common guides in the decisions as to what fertilizer materials to use. They are leading the farmer to understand, and to be more concerned about, his soil fertility problems. It is that growing concern of the farmer rather than the clever selling ability of the fertilizer agent which has recently increased the fertilizer sales very pronouncedly. Any salesman will distribute more fertilizer when his sales are soil-test-guided to balance by that the fertility of the particular soil to be treated.

The farmers, given more contact with soil-testing laboratories, are studying soil science—not just practices—most diligently. They are accepting the basic concept that the field soil need not be a uniform medium as to degree, either of acidity or of saturation by all the essential plant nutrients. Rather, the soil may be a mixture representing a heterogeneous collection of foci of each of these with even the mineral or rock forms weathering slowly while in contact with the acid clay. Plant growth may then represent the summation of root contacts with all these different centers of fertility as the roots move to and get from them all that is needed for maximum crop productivity. According to this concept, both the very soluble and the less soluble nutrient materials applied in granular form would maintain this seemingly beneficial heterogeneity of fertility sources for better plant growth than would any practice aiming to blend the soil to the uniformity with which nutrient solutions are endowed, or as the "ideal" soil is apt to be envisioned. The fertilizer industry must study soil science too if its services by fertilizers are to sell these productions and each sale be the means of making many more.

VIII

"Fertilize for more proteins by all means" may well be the slogan for all of us. The services by fertilizers will increase, and thereby sales of them will increase too, when the soil is still more closely connected with nutrition by our knowledge of the neglected trace elements functioning in our soils, our crops, our animals, and ourselves. Enzymes, which are the catalysts to speed up biochemical reactions, usually consist of three components, namely, some "trace" element, a protein-like part, and a vitamin-like unit. That chain of elements and compounds links the soils with the dynamics of creation and maintenance of life very directly. As tools, the magnitude of the mass of the enzyme is not an index of the magnitude of its service. Hence "trace" elements become very important in their very small amounts. Significance attaches itself to "trace" elements when they are active in the synthesis of proteins, and when their shortages have been connected with shortages of the most commonly deficient amino acids, methionine and tryptophane, and with the nitrogen fixation process by legumes. In terms of the problem of protein production, the trace elements in a larger number become as significant as is the neglected element magnesium in chlorophyll and its synthesis of the carbohydrates. When the "major" elements, which we recognize in terms of their amounts available in correlation with the magnitude of the products created, are so badly needed as fertilizers, then surely the "trace" elements as tools, which are controlling the magnitude of production, become even more significant in our soil treatments.

THE LIMITED SUPPLIES OF FERTILIZER
RESOURCES DEMAND KNOWLEDGE AND THRIFT
IN THEIR USE FOR MORE AND COMPLETE
PROTEINS, NOT JUST ANY FOOD.

Fertilizers, to date, represent about thirty per cent of our agriculturereal production, that is, **our creation—not transformation**—of new values, and of food values at that. With the recognized inadequacy of potential fertilizer resources for them to assume the complete production of food, it behooves us to learn the chemo-dynamics of the production still resulting from the fertility resources coming from the soil's virgin supply. Fertilizers are still only a bit of nutritional supplement, but the finishing supplement, to what the crop plants rustle up for themselves from the soil. It behooves fertilizer producers then to fit their products into the soil's need for plant nutrition. In connection with that service, fertilizer producers, distributors, and salesmen must therefore be better students of soil science in order to appreciate the importance of the following:

(1) the climatic setting according as the degree of soil development in it represents soil under differing degrees of construction or under differing degrees of destruction;

(2) the clay content and clay nature of the soil representing high or low exchange capacities for extensive or limited stocks of fertility, or disturbing amounts of hydrogen ions;

(3) the supply of fertility reserves in the silt mineral fractions, virgin to the soil, and washed in or blown in on it, but yet to be broken down by the root activities resulting from carbonic acid output, and serving as a sustaining fertility over a long time;

(4) the ratios of the activities of the different nutrient cations and anions offered by the soil colloidal organo-inorganic complex representing suitable amounts and ratios exchangeable for the root's cation, i.e., hydrogen, and the root's anion, i.e., bicarbonate;

(5) those ratios of the nutrient ions controlling the plant's synthesis largely of carbohydrate bulk only, or its synthesis also of proteins complete in all the amino acids required for the nutrition of plants, animals, and man; and

(6) the organic compounds in the soil to supply not only those required for plant nutrition of highest order, but all compounds contributing secondarily, via microbes as well as plants, to make the soil provide nutrition for ourselves as **body growth, body protection against degenerative diseases, and body reproduction in healthy offspring.**

Fertilizers must move into the high service of real nutrition via the soil. The producers, distributors, and salesmen of them have a large opportunity—but a larger responsibility also—to give that service. The provision of it is a great challenge. We are confident that it will be accepted readily by the men in the fertilizer industry.



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