THE TRACE ELEMENTS

by Warren L. Anderson

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Our Compliments to Warren L. Anderson also to Hoard's Dairyman, Fort Atkinson, Wisc., who printed these three articles in their publication --- Hoard's Dairyman

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Article One...

By WARREN L. ANDERSON

The most valuable packages are often the smallest. So it appears to be with trace elements, vitally important to crops, livestock, and humans.

Small things make base men proud.
—Wm. Shakespeare—

BACK in the days when America was in knee breeches and Daniel Webster was a senator from Massachusetts, the brilliant New England orator is reported to have wisely remarked that farmers are the founders of civilization. He might well have added that if civilization is to endure, it will be only because modern farmers regard as true the old adage, "You get out of a thing only as much as you put into it." Good seed is the forerunner of a good crop; good breeding a prerequisite of prize livestock.

Fortunately, many farmers realize that what was good enough in the days of "Black Dan" is not good enough today. Things have changed. The old gives way to the new and the accompanying progress that comes with time forces any farmer to keep abreast of the advances in farm machinery and management, soil conservation, and feeds and fertilizers if he'd rather use black than red ink in his yearly books.

A part of this forward step toward higher yields and lower costs deals with the trace elements, more properly called the micro (meaning: small) nutrient minerals. The story of these micronutrients is new and, at the same time, old.

Two Ounces of Soil - 160 Pound Tree

For example, look at the work of Dr. J. E. Steckel, now on the staff of Pennsylvania State College. Three years ago, when Dr. Steckel was a graduate student at Purdue, he added one of the trace elements—manganese—to the soils of Northern Indiana and increased soybean production from 15.1 to 27.4 bushels per acre. On the other hand, we can go back three centuries to when Jean van Helmont, a Belgian chemist and physician, helped lay the groundwork for much of our present-day experimental agriculture and unknowingly gave us proof of the importance of minerals in plant life.

It was during the middle of the 17th century that van Helmont planted his famous five-pound willow tree in 200 pounds of dry earth. For five years he added nothing but rain water to the soil and his tree grew to weigh more than 169 pounds while the dirt, dried and reweighed, had lost only two ounces. His conclusion: plants are formed solely from water.

What the good doctor didn't know, of course, was that the tree had taken carbon and oxygen from the air, that bacteria in the soil had helped to make nitrogen available, and that the water itself, in addition to supplying hydrogen and oxygen, carried a few elements with it.

But van Helmont and Steckel were rowing the same boat; both aimed at explaining some of the complex processes of plant life. Each man, although van Helmont didn't realize it, was enlarging our understanding of the trace elements and their role in producing and maintaining the health of plants and animals. The application of their findings, along with countless other scientists, is already paying progressive farmers in dollar-and-cents dividends.

Good Health on Fertile Soil

The earth and its atmosphere, as we know them today, are made up of

92 elements, natural occurring substances that are not decomposed during chemical change. By themselves or in myriads of combinations, they constitute all inanimate and living things.

Growth and the maintenance of health have been proved with varying degrees of certainty to be associated with at least 37 of the almost 60 elements that are found in either plants or animals. Forcefully brought to the country's attention as the records of World War II became available, the importance of these elements in nutrition is still not fully appreciated. In some of our southern states, particularly Arkansas and Louisiana, where the soils are known to be farmed out and lacking ample amounts of the micronutrient minerals, the services had to reject better than 40 per cent of all registrants examined during the first 38 months of the draft. At the same time, however, the more fertile, lush fields of Washington and Kansas yielded men who were rejected at a rate of less than 23 per hundred.

Such figures speak for themselves. The better the land and the farming practices, the better the men. Good health was and is more the rule and less the exception where sufficient quantities of the essential elements are present in the soil.

Four of these elements—carbon, nitrogen, oxygen, and hydrogen—make up approximately 95 per cent of the dry weight of all plants. The major ash elements—calcium, phosphorus, and potassium—compose most of the remainder. Some of these are furnished by nature as rain or as constituents of soil. The others are ones the farmer sometimes purchases by the ton and systematically spreads on his fields. But he is very apt to forget about the trace elements.

Because these micronutrient minerals are needed in such minute amounts, there is the feeling that they are not as necessary as those needed in bulk. After all, they account for only one per cent of the total weight of plants, a fact that is not always rung up in the savings deposit at the bank. Nevertheless, it is this too often overlooked one per cent that can mean the difference between 45 and 60 bushel corn, the difference between a prize hog and a runt.

"Those elements that are essential for life," according to one authority, "are all equally important, though the quantity that is required of one may be very small in relation to that of another." Plants need only small traces of zinc. They need large amounts of available phosphorus in the soil. Yet a deficiency of either element can ruin an otherwise good crop.

Food in Large and Small Packages

The essential minerals for plant and animal life are sometimes divided into two groups. Calcium, phosphorus, and sulfur, along with sodium, potassium, chlorine and magnesium are classified as the macro or "big" nutrient minerals. This high-sounding title has nothing to do with their importance. It's used simply because these elements are needed in bigger amounts by plants or animals, or both, than are micro-nutrient minerals.

This second division, the micronutrient or trace minerals, is today receiving more and more attention. It includes iron, copper, zinc, and manganese as essential for both plant and animal life, boron and molybdenum as necessary for plants, and iodine and cobalt as indispensable for animal life. These are all required in comparatively minute quantities. The human body contains only about three parts per million of manganese, and plants only about one-hundredth of one per cent. Zinc occurs in plants in amounts smaller that 50 parts per million.

How these trace elements operate is still somewhat of a mystery. Scientists readily admit that the subject has more ifs, ands, and buts than a pickle has warts and that there's still a lot to be learned. It is

known, however, that some of them are built directly into the tissues of animals or plants.

Iron is an essential part of blood and copper a necessary component of green plants. Cobalt is present in the recently discovered vitamin B-12, the anti-pernicious anemia factor, while boron is fundamental if new plant roots are to develop properly. Molybdenum, so nearly present on a universial scale that you don't have to worry about it, is believed to play a role in the metabolism of nitrogen in plants.

Some of the micronutrients are what the chemist calls catalysts. Others, when in combination with proteins, are intricate parts of essential enzymes. These catalysts and enzymes have the not too well understood task of being necessary for particular chemical reactions without actually entering into the processes. They only help make it possible. It's similar to your morning cup of coffee. It doesn't become a part of the coffee at all. It just helps to make it possible.

In a comparable but more complicated process, copper is a catalyst in the blood formation and manganese a probable part of the enzyme that allows carbon to be utilized by plants.

Boron Needed by Plants

One of the chief difficulties connected with the proper use of the micronutrient minerals is the narrow range that sometimes exists between soil concentrations that will correct deficiency symptoms and those that will cause toxicity. A striking example of this is found in the case of boron, an element essential only to plants. Some plants will show boron deficiencies when a soil solution contains less than 0.01 part per million of the element, but toxic conditions may develop when the amount is above 1.0 part per million. These amounts although extremely small and impossible of measurement by the farmer, are important and can be translated into usable quantities of boron.

The element is usually added to the soil as borax in amounts great enough to meet local soil and crop conditions. Out in Oregon 30 pounds to the acre, spread in the early spring, will prevent the cracking of cherries, prunes, and celery in rainy weather. The olive growers of neighboring California put one pound of borax around each olive tree and have found the amount ample to prevent the development of "monkey faces." But the same amount is too much for plums or pears. On these trees only one-half pound is used.

In Florida the boron compound is used to prevent cracked celery at one-third the amount used in the West. Ten pounds per acre is plenty. More is toxic. Fruit growers in the Peninsula State sometimes use it, too as a spray on their fruit trees at the rate of one or two pounds in 100 gallons of lime sulfur per acre.

Some farmers in the Middle West have learned that the "yellows" of alfalfa can often be cured by boron applications. This deficiency is characterized by the yellowing of the top leaves and buds of the legume, but these same conditions when caused by leafhopper injury, won't be corrected by borax. Thirty to 35 pounds of borax, however, has corrected the "yellows" in Southern Illinois when leafhopper damage wasn't the cause of the trouble. This application costs about $1.50 an acre and can be made any time of the year or when the crop is seeded. It will last two or three years and will prolong the life of the stand just as long.

Table beets show a boron deficiency by black spots throughout the fleshy roots. Forty pounds of borax to each acre will usually correct the shortage. When sugar beets, on the other hand, show the heart rot that leads to a lower sugar content, only 10 pounds to the acre is needed.

Be Careful!

These varying amounts of boron that can be successfully used show the extreme care that must be exercised when the element needs to be and is applied. As Dr. Matthews Drosdoff of the Florida Experimental Station emphasizes, "The use of more that 20 or 30 pounds of boron an acre will cause injury to some plants. yet as little as 5 or 10 pounds to the acre may save an apple crop."

In the case of borax, as with all of the trace elements, before you apply them to your soil or feed them to your livestock, have a talk with your county agent. If they cannot give you the help you want, write to your state agricultural college or experiment station and find out what elements are known to be lacking from the soils in your particular locality. Use those missing elements as a part of your farming program. But use them only as directed. Don't operate with the old but wrong idea that if a little bit helps, a lot more will work miracles.

(*Editor's Note*: This is the first of a series of three articles dealing with the recognition and correction of trace element deficiency symptoms in plants and animals.)

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Article Two . . .

W. L. ANDERSON

There is probably no such thing as a one element shortage. All fertilizer elements are a part of a life and death pattern in a very definite spot with a definite job.

THERE'S been a lot of talk during the last few years about the marvelous results that can be obtained when the trace elements are used in feeding and fertilizer programs. While it is quite true that these micronutrient minerals often bring about cures that are nothing short of miraculous, it is equally as true that they may raise all kinds of havoc when they're not handled properly.

But even before any thought is given as to whether or not trace minerals should be used, there's another big and equally important point to be considered: Does your land have enough of the micronutrients in it to support the plants you're trying to grow on it? Dr. Frank Gilbert of the Battele Memorial Institute in Columbus, Ohio, says: "Eighty per cent of the farmers in America need to use more nitrogen, potash,phosphorus, and limestone. No amount of the trace elements will help them unless they first make sure that they have ample quantities of these essential plant foods in the soil." That's pretty sage advice and well worth following. It's the main reason why the various soils in your different fields should be analyzed regularly.

Manganese and Beans

Manganese is one of the trace elements that is helping progressive farmers raise more and better plants on less land. Scientists believe that this essential mineral plays a role in the formation of chlorophyll, the chemical compound that makes plants green and allows them to form carbohydrates from carbon dioxide and water.

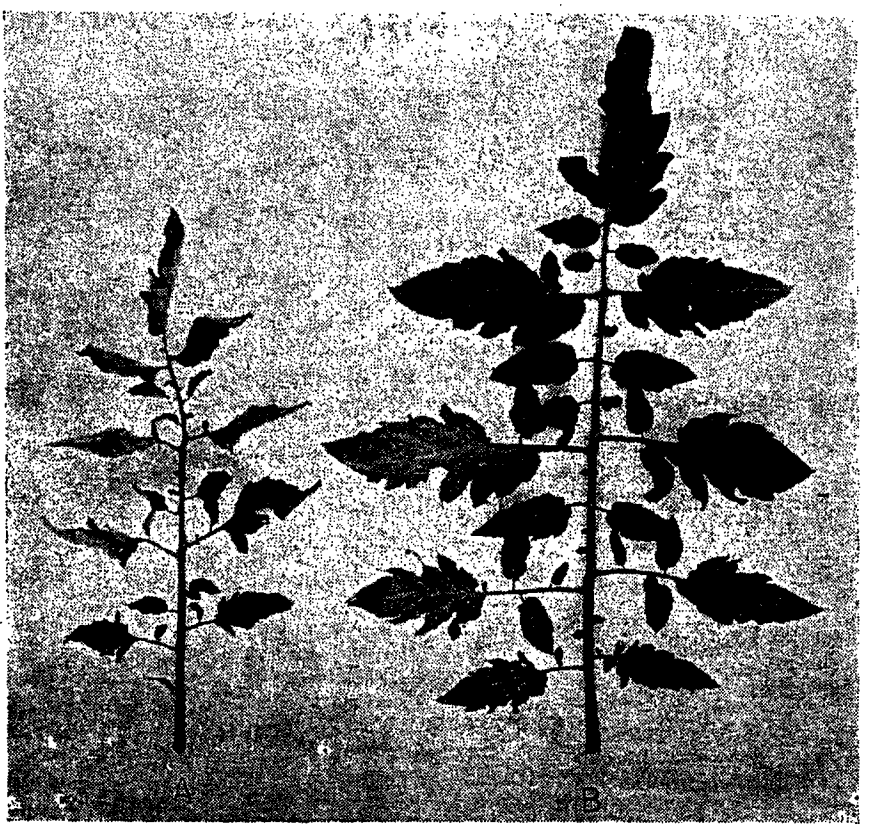
Some plants show manganese de-

ficiency by a peculiar mottled type of chlorosis—a yellowing or blanching of the normally green parts—in which the areas between the veins become yellow while the veins themselves remain green. Yellow leaves and low quality fruit are deficiency signs of manganese in navy, string and soy beans, conditions that generally can be corrected by using 100 pounds of manganest sulfate per acre either as broadcast before planting or as a side dressing. It should never be put down with the seed.

While these deficiency symptoms are sometimes brought about by an actual lack of manganese in the soil, it is quite possible that they may simply be due to overliming. The element must have an acid soil in order to function properly.

Iron Not a Problem

Iron, like molybdenum, is an element about which most farmers need not worry. Widely distributed in the earth's crust, it will ordinarily be unavailable only in very alkaline soils. The one important thing to be considered when it and the other micronutrient minerals are used in a fertilizer program is that there is a definite iron-magnesium ratio that needs to be maintained. Plant pathologists have proved that these elements are interrelated, that the effectiveness of one is determined by the proportionate presence of the



The leaf at the left is from a plant grown in copper-free nutrient solution. At the right a plant grown with copper.

other. According to Dr. I. I. Somers, who studied the problem at the New Jersey experiment Station, symptoms of iron toxicity correspond to those of manganese deficiency, and symptoms of manganese toxicity correspond to those of iron deficiency. In other words, symptoms produced with excessive iron are identical with those produced when managnese is deficient, and vice versa. A deficiency of iron may be suspected when the leaves of plants turn yellow, starting with the young growth.

The Citrus Industry

The relationship in plant life between zinc, copper, and other minor elements has recently received a good deal of well earned publicity. The past 15 years have seen remarkable strides in the Florida citrus industry where copper, zinc and manganese, sometimes supplemented with boron and iron, have been used to prevent as well as cure trace element deficiencies. To spray copper, zinc, and manganese costs about $5.00 an acre per application. To spread them as fertilizers costs $12.00 an acre. But the spray will ordinarily have to be used four times each season while a spread will have to be applied only once.

Copper deficiency is called "dieback" for the obvious reason that the large citrus leaves die back before they are fully developed when the element is lacking. A zinc deficiency is termed "frenching," while marl chlorosis is the description applied to the foliage of manganese deficient trees.

None of these or the other micronutrient can act alone, regardless of what plant is involved. There is probably no such thing as a one element deficiency. They all fit into the life and death pattern of life in a very definite spot and with a very definite purpose. As scientists continue to explain the functions of these various elements, we will be better able to use them more exactingly. In the meantime, their usage must be determined by the recognition of symptoms that are correctable with proved amounts on specified soils and crops.

Animals Need Iodine

A very wise man once said that if you allow a pig to make a hog of himself, he'll do it a lot faster than you can. Such a prediction, which assumes that all of the macro and micronutrients are available to the young porker free choice, includes iodine. Known as the "anti-goiter element," it is foremost among the trace elements that have gained public recognition in human and animal nutrition. Before iodine compounds were regularly added to grocery store salt, goiter was very common among the people living in the Great Lakes region. Generally characterized in humans by an enlargement of the thyroid gland, iodine deficiency also shows up in animals as goiter or, in newly born pigs as hairlessness.

The goiter belt, extending from Pennsylvania westward across most of the northern half of the United States, is an area wherein iodine must be added either directly to animal and human rations or else to the soils. While the element is not essential for plant growth, plants will absorb it and pass it on. In fact, some nutritionists are advocating that iodine should be added to fertilizers. They believe that plants can absorb enough of the element to offset any possibility of a deficiency developing in the animals or the people dependent upon those plants as food.

The simplest and cheapest way to be sure that all stock receives plenty of iodine is to feed iodized salt or one of the free choice salt mixtures containing it. Nearly all manufactured feeds contain iodine. The cost of putting it and the other trace elements into feed adds up to about ten cents per ton. That's probably the cheapest insurance on the market today, considering the protection it offers.

Your Children's Teeth

Chemists have been working with one of iodine's first cousins during

the last few years and have come up with a way that will help prevent dental cavities. The element fluorine, while it has never been proved essential to either plants or animals, apparently has a place in the maintenance of human health and deserves mention along with the other trace minerals. Properly used, it can save future generations a lot of money insofar as dental bills are concerned.

A fluorine salt applied by the dentist to the teeth of growing children will, in some instances, prevent cavities from developing. In certain areas of the country where just the right amount of fluorine is naturally found in the drinking water, cavities and dentists are very scarce. But like boron, a slight excess of the element can cause trouble. In this case, too much fluorine results in mottling or spotting of the teeth.

Dentists have all the details of the treatment—it's relaively inexpensive, quick, and painless—and can apply the proper fluorine chemical to children's teeth. Sufficient studies have not yet been made to determine the effect of similar applications on adults' teeth.

(Editor's Note: This is the second in a series of three articles dealing with the recognition and correction of trace element deficiency symptoms in plants and animals.)

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Article Three...

W. L. ANDERSON

With every extra bale of hay or bushel of grain per acre, not only nitrogen, phosphate, lime, and potash are removed. The trace elements, too, are drained from the soil reserves.

WHEN a man loses 1,100 of his 1,300 sheep and then finds out that a trace element deficiency was the cause of death, that man suddenly comes to realize the importance of the micronutrient minerals. Mr. Harold Volland of Shawano County, Wisconsin, recently had this unhappy experience and until he began to feed cobalt to his sick sheep, he was certain he was going to lose his entire flock.

The necessity of cobalt in the health of animals was first noticed by sheep men in New Zealand and Australia. Animals in certain areas began to waste away, and the trouble came to be known as "coast disease," "bush sickness," or "the skinnies." Experts believed it was due to a lack of iron and promptly added pure iron to the ration. But the animals kept right on getting sicker and sicker. When an impure form of iron, however, which was later found to be effective because of the cobalt contained, was added to the ration, the animals immediately perked up and the disability disappeared.

When cobalt is lacking from the ration, animals lose their pep, their appetites, and become anemic looking. Lowered resistance increases their susceptibility to pneumonia and parasites. Ewes fail to settle, and too many lambs are born dead while the living ones are weak, fail to put on weight, and finally waste away and die.

Cattle Need Cobalt, Too

While cobalt sometimes seems to be more necessary for sheep than other stock, cattle are also affected when

the deficiency is pronounced. They may get wasting troubles which in the South is generally known as "soil sickness," "grass sickness," "hill sickness," "scrub sickness," and even "sea sickness." In Michigan it's called "neck ail."

Characteristic symptoms of all cobalt deficiency diseases include improper shedding of the coat, falling hair, bleaching around the lips, watery eyes, and apparent nausea when faced with feed. In slight cases the animal may live for years. Growth will be slow and stunted. Sterility or abortion may occur in breeding females.

Prepared dairy rations usually contain an ample amount of cobalt to prevent any of these symptoms from developing. But if manufactured feeds are not used, a trace mineral mixture or a cobalt solution will generally correct and prevent deficiencies. In the case of calves receiving milk, 1 ounce of cobalt sulfate in a gallon of water is a basic solution. Feed 1 or 2 teaspoons of it to each calf every day. Cattle not receiving milk should get one-half to 1 ounce of the same compound mixed with every 100 pounds of salt.

History in Missouri

An experiment is underway in Springfield, Mo., that has caused considerable controversy in the agricultural and medical fields. It is concerned with Bang's disease and its counterpart in man, undulant fever.

Bang's disease costs the American farmer about $100,000,000 a year. But no one knows the price or incidence of undulant fever. Estimates of its occurrence run up into the millions. Edsel Ford, Henry's son, died of it after he had drunk infected milk. Similar to infantile paralysis, it strikes rich and poor alike.

Some Missouri men believe that when humans or animals fail to receive ample quantities of essential trace elements, both are more susceptible to the germ that causes Bang's disease or undulant fever and less able to fight off the infection that may result. Only time and further

Cobalt was lacking in this young bull's feed

experimentation will prove whether or not they are correct.

Research Needed

This work is in many ways giving emphasis to the University of Missouri's Dr. William Albrecht and his "philosophy of the soil as the basis of nutrition of the microbes, of the plants, of the animals and therefore of man at the top of the biological pyramid." To better round out our understanding of all of the micronutrient minerals, many years more of research are needed.

But there is enough known about several of the trace elements at the present time to meet the requirements of most farmers and their fertilizer dealer problems. Blanket recommendations, however, cannot be made because of the differences in soils throughout the country. The men who should advise you are your county agent and the soil chemists at your state experiment station.

There are, nevertheless, several factors and conditions which appear to be commonly associated with trace element deficiencies. Wherever these conditions are encountered, the grower should watch his crops closely for deficiency symptoms and should apply corrective supplements when indicated. Dr. C. B. Harston and Glen Fuller of Battelle Memorial Institute call attention to five such situations:

(1) **Heavy Use of Lime:** For a great many soils and for certain crops, heavy applications of lime are necessary, both to supply available calcium and to produce a favorable soil reaction. However, it has been demonstrated that tract element deficiencies, notably of boron, iron, and manganese, may be induced by liming. Soils that are naturally strongly alkaline may exhibit deficiencies for much the same reason.

(2) **Leaching and Erosion:** In areas where rainfall and soil temperatures are favorable to the breakdown of organic material, both major and trace nutrients are readily removed from the soil by leaching. Severely eroded areas are even more completely depleted of essential minerals. Deficiencies of all of the trace element should be anticipated under these conditions.

(3) **Heavy Cropping:** For every extra bushel of corn or bale of hay per acre, whether through the use of improved varieties and hybrid seed, liberal application of commercial fertilizer, or better cultural methods, proportionately more of the essential trace elements are being taken from the soil. Modern high analysis fertilizers rarely contain sufficient trace elements, as impurities, to replace the amounts removed by heavy cropping. Sooner or later the trace element supply of the soil will become depleted and will have to be replenished if production is to continue at a high level.

(4) **Organic Soils:** While a reasonably high organic matter content is a desirable feature of agricultural soils, the predominantly organic soils, such as mucks and peats, frequently exhibit trace element deficiencies. These are usually the result of a fixation or immobilization of the elements rather than of their absence.

(5) **Inherently Deficient Soils:** Certain soils have been formed from parent materials lacking in one or more of the essential trace elements. That is, they are basically deficient irrespective of the cultural practices, lime, and fertilizer applications or cropping systems to which they have been subjected. As knowledge is accumulated on the origin and development of soil types, it may eventually be possible to predict where deficiencies can be expected on the basis of the geological history of the soil. As yet, this is not feasible and such conditions have to be recognized by the warning signals displayed by our crops.

Check and Double Check

If the corn, wheat, oats, barley, and other crops that you grow are sickly even after you've checked these points and made certain that your land has plenty of nitrogen, potas-

sium, phosphorus, and calcium, it's time to use the trace minerals.

And if, in addition to the feed you're raising, you have a garden in which most of your own vegetables are grown, chances are that not just your stock and crops but you, too, are in need of the micronutrient minerals.

None of the deficiencies may be marked enough to show up as goiter or of any of the other visible diseases that nutritionists blame on improper food. But they can very possibly be borderline cases that result in chronically exhausted men, children that are always sick or a cow that dries up before her time.

Some medical men are coming to believe that we have only one major disease: malnutrition. If further experimentation substantiates and enlarges this idea, it becomes increasingly important that our farming practices incorporate all of those controllable factors that are essential for the proper nutrition of the plants and animals by which men live.

This will of necessity make the farmer of tomorrow a scientific farmer who understands nature and allows it to act as it was made to act. He cannot change it; he can only guide it. But that guidance must include all of the elements necessary for the universal health that will naturally precede a lasting universal peace.

THE END.

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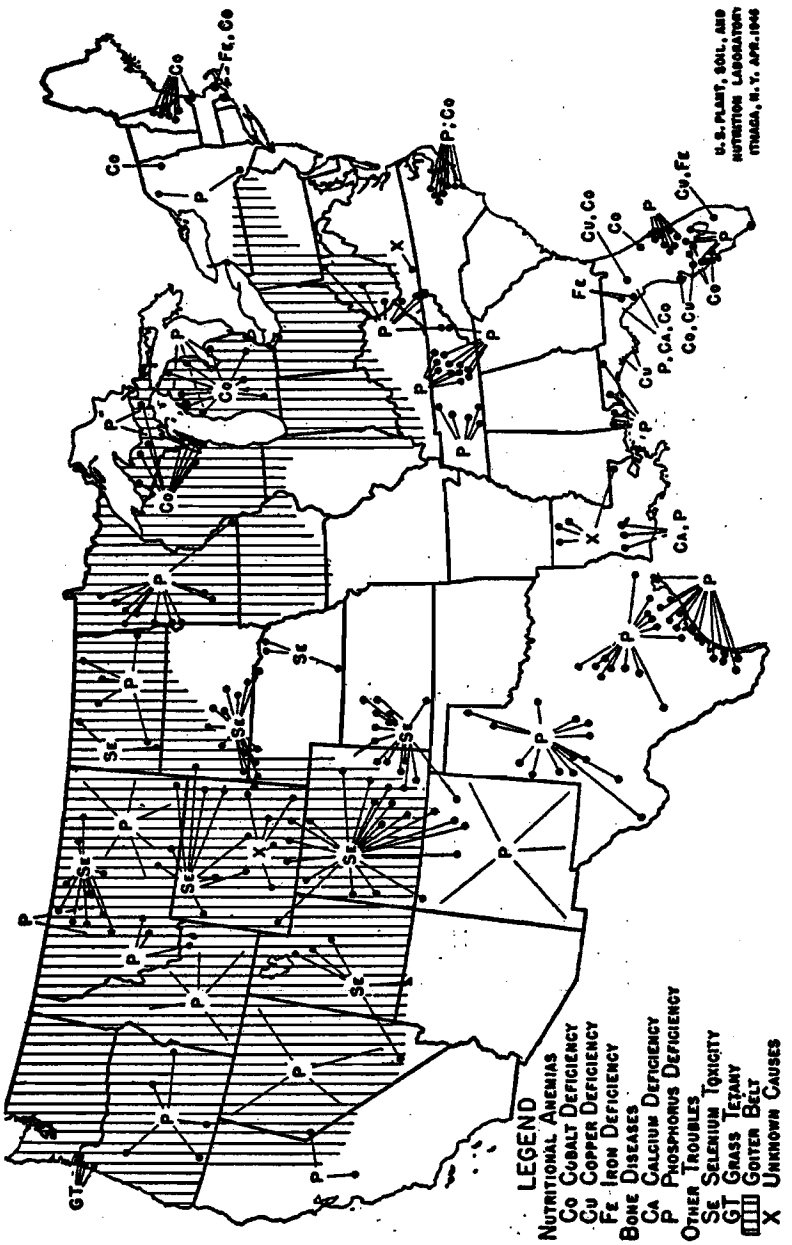
About the Author . . .

As a result of his research activities, Warren L. Anderson became intensely interested in trace elements or trace minerals. A graduate of the Illinois Institute of Technology, Anderson has been a nutritional research chemist with one of the nation's largest packers and has taken advanced work in Northwestern University's graduate school in the Department of Biochemistry at the medical school. He was a Research Fellow in the Department of Clinical Science, University of Illinois.

In the preparation of this series of three articles, he reviewed over 500 research papers and consulted more than 30 of the leading scientists in the field.

—The Editors.



This map shows known locations of mineral nutritional diseases in animals. The editors believe that deficient areas will increase as we learn more about deficiency symptoms and are able to more accurately measure available and required trace elements.

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