BETTER CROPS
WITH PLANT FOOD

Winter 1990-91

Featured in this issue:





Best Management Practices Begin With **THE DIAGNOSTIC APPROACH**



BETTER CROPS With Plant Food

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Vol. LXXV (75), No. 1 Winter 1990-91

BETTER CROPS WITH PLANT FOOD (ISSN: 0006-0089) is published quarterly by Potash & Phosphate Institute (PPI), 2801 Buford Hwy., N.E., Suite 401, Atlanta, GA 30329. Phone (404) 634-4274. Subscriptions: Free on request to qualified individuals; others $8.00 per year or $2.00 per issue.

Contents

MODERN AGRICULTURE must properly use every tool and practice available to produce efficiently, profitably and in concert with a clean environment. Farmers using this approach employ a system of **best management practices (BMPs)**. That system should include "The Diagnostic Approach."

The use of soil testing and plant analysis and the understanding of visual symptoms are important to scientists and growers alike as they fine-tune diagnostic techniques.

It is hoped that this publication will be useful to teachers of high school and introductory college courses, to Extension specialists and county agents, to members of the fertilizer, agrichemical and seed industry, to soil conservationists and to consultants. Farmers could find it helpful in better understanding the diagnostic approach. Reprints of this publication are available from the Potash & Phosphate Institute under the title of *The Diagnostic Approach*.

T.J. Wright Elected Chairman, R.G. Connochie Vice Chairman of PPI and FAR Boards of Directors

THOMAS J. WRIGHT, President and Chief Operating Officer (COO) of Texasgulf Inc., a division of the Elf Aquitaine Group, has been elected Chairman of the Potash & Phosphate Institute (PPI) Board of Directors. He will also serve as Chairman of the Foundation for Agronomic Research (FAR) Board. **Robert G. Connochie**, Chairman and President of the Potash Company of America, Inc. (PCA), is the new Vice Chairman of the PPI and FAR Boards.

T.J. Wright

R.G. Connochie

"We are very pleased to have Tom Wright and Bob Connochie assume their new leadership responsibilities with PPI and FAR," said Dr. David W. Dibb, President of PPI. "Our efforts in market development through agronomic science will benefit by our association with such well-respected industry leaders."

Mr. Wright, in addition to his position with Texasgulf Inc., is President of Tg Soda Ash, Inc.; Senior Vice President of Elf Aquitaine, Inc.; Vice Chairman of the Board for Texasgulf Export Corp.; and Chairman of Moab Salt, Inc. He also takes an active role in other organizations that serve the fertilizer industry, such as The Sulphur Institute and The Fertilizer Institute (TFI).

Mr. Connochie is also a dynamic industry leader. Currently, he serves as Director and Chairman of Canpotex, and Director for both the Saskatchewan Potash Producers Association and TFI.

In other action of the PPI Board, **Mr. René Latiolais** of Agrico Chemical Corporation was elected Finance Chairman and **Mr. Charles E. (Chuck) Childers**, former Chairman of the PPI Board, was named Chairman Ex Officio. Four other individuals representing member companies have been welcomed to the PPI Board of Directors. They are: **Richard H. Block**, President, Agrico Chemical Company; **Henk M. Mathot**, President, Gardinier, Inc.; **William S. Holt**, President, Great Salt Lake Minerals & Chemicals Corporation; and **C. Steve Hoffman**, Senior Vice President, Domestic Wholesale Marketing, IMC Fertilizer Group, Inc. Mr. C.C. (Kip) Williams was elected Honorary Lifetime Director. He served as Chairman of the Board during 1986-1988.

Dr. Bob C. Darst, President of FAR, also announced other actions following the recent annual FAR Board meeting:

- **Mr. Gerald J. Quinn**, Director of Market Development, Agricultural Products Division, ICI Americas Inc., was elected to the FAR Board of Directors.
- **Dr. Larry S. Murphy**, Senior Vice President of PPI, was also elected to the FAR Board.
- **Mr. Jack Satterwhite**, President, ConAgra Fertilizer Company, was elected to the Executive Committee of FAR.
- Two individuals were named Vice Presidents of FAR, although not members of the Board. They are: **Dr. W.R. Thompson, Jr.**, Midsouth Director of PPI, and **Dr. Noble R. Usherwood**, Vice President and Southeast Director of PPI. ■

The Complete Crop Diagnostician

A CROP DIAGNOSTICIAN looks beyond fertility problems, and soil tests for phosphorus (P) and potassium (K) and other nutrients. The diagnostician must know and understand all those field conditions that impact on crop growth.

Such knowledge may help pinpoint a problem that is inducing or magnifying apparent nutrient shortages. Look at all factors that influence crop growth, response to fertilization, and final yield.

1. Root zone — Soil must be granular and permeable for roots to expand and feed extensively. A crop will develop a root system 6-feet deep or more on some soils to get water and nutrients. So, it is desirable to know the fertility level of the subsoil. A shallow or compacted soil does not offer this root feeding zone. Wet or poorly drained soils result in shallow root systems. Proper drainage is of key importance in early crop growth.

2. Temperature — Cool soil temperatures slow organic matter decomposition. This limits the release of nitrogen (N), sulphur (S) and other nutrients. Also, nutrient uptake is slower in cool soils, increasing deficiency potential. Nutrients diffuse more slowly in cool soils. Root activity is decreased.

3. Soil pH — Acid soil conditions reduce the availability of calcium (Ca), magnesium (Mg), molybdenum (Mo) and P. Acid conditions increase the availability of iron (Fe), manganese (Mn), boron (B), copper (Cu) and zinc (Zn). Nitrogen is most available between pH 6.0 and 7.0.

4. Insects — Don't mistake insect damage for a nutrient deficiency. Examine roots, leaves and stems for insect damage that may cause similar symptoms.

5. Diseases — Close study will show the difference between plant disease and nutrient deficiency. The disease symptoms can often be detected with a small hand lens.

6. Moisture conditions — Dry soil conditions may create deficiencies. Boron, Cu and K are good examples. This is why crops respond so well to such nutrients when they are well supplied in dry periods. Drought slows movement of nutrients to roots.

7. Soil salinity problems — Soluble salts and sodium (Na) are problems in some low rainfall areas. These conditions may occur in just part of the field — usually where a high water table exists, where poor quality water has been used for irrigation, or where seepage water reaches the surface.

8. Weed identification — Herbicides and mechanical controls are more important today than ever before. Weeds rob agronomic plants of water, air, light, and nutrients. Some weeds may even release substances that inhibit crop growth. Learn to identify weeds and to know the materials used to control them.

9. Herbicide damage — Under certain conditions plants may suffer from carryover herbicides or those applied the current year. Be aware of possible drift from adjacent fields. Herbicide injury may also be affected by soil pH. Know the symptoms of herbicide damage and the interactions of herbicides with soil conditions.

10. Tillage practices — Some soils develop hardpans and require deep tillage. In conservation tillage, much of the fertilizer is broadcast and is on or near the surface. More P and K may be needed to build fertility. Band placing of some of the fertilizer near the seed may be helpful in such cases.

11. Hybrid or variety — Yield potential and adaptability to a given environment affect how a crop performs.

12. Plant spacing — Row width, uniform spacing of plants in the row and number of plants per acre are important to yield.

13. Water management — Adequate drainage, either surface or tile, is the key. With irrigation, time and amount of water are of prime importance in good crop growth. Learn what the irrigation program has been.

14. Date of planting — This will affect rate of growth and plant appearance, as well as final yield potential in some cases.

15. Fertilizer placement — Under many conditions a small amount of fertilizer near the roots is important for a fast start. The fertilizer may have been applied broadcast or too deep. Strip or deep banding may be effective in some situations.

Importance of Cultural Practices

Knowing what has been done in a field before going into that field can be one of the most important diagnostic techniques.

Get the facts . . . cropping history . . . planting date . . . seeding rate . . . variety . . . row width . . . tillage practices . . . depth and method of planting . . . past fertilizer and soil amendments . . . past weather conditions.

Remember: The more that is known about a field before entering, the better it can be diagnosed.

Get the facts systematically. And record them! A checklist will avoid forgetting key information. See the following "Crop Production Checklist" as an example. ■

Crop Production Checklist for Maximum Economic Yields (MEY)

Grower ______
Address ______
Telephone ______

Date ______ Field Number/Name ______
Crop ______
Location ______
Consultant ______

Soil and Tillage Information
Tillage method: Moldboard Plow ______ Chisel ______ No-till ______ Other ______
Soil type ______
Describe primary tillage method ______ Date ______
Describe secondary tillage methods ______ Dates ______
Other comments on soil and tillage: ______

Cropping Information
Acres ______ Yield Goal ______ Top Yield to Date ______
Variety or hybrid ______ Seed dealer ______ Crop Last Year ______ Yield ______
Seed: Germination % ______ Vigor test ______ Other details ______
Row spacing (in.) ______ Seeding rate ______ Depth ______ Planting date ______
Final population (plants/acre) ______ Harvest date ______

Field appearance: Poor ______ Fair ______ Good ______ Excellent ______ Other ______
Obvious deficiency (D) or toxicity (T) symptoms:
N ______ P ______ K ______ Ca ______ Mg ______ S ______ B ______ Zn ______ Cu ______ Mn ______ Fe ______ Other ______

Field Tissue Tests: (VL, L, M, H, VH) Plant part ______ Method ______ Date ______
Best area: N ______ P ______ K ______ Other ______
Poor area: N ______ P ______ K ______ Other ______
If additional tests are done, note here and attach a record of results.

Have plant analyses been taken from problem areas? ______ When? ______

When were soil samples last taken? ______ Results available? ______

Fertilization Practices

Method		N	P_2O_5	K_2O	Secondary Nutrients	Micronutrients
		pounds applied per acre				
Broadcast	Before Plowing					
	After Plowing					
	Topdress					
Row	Starter					
	Beside/below seed					
	With seed					
	Sidedress					
Foliar						
Other (manure, rate)						

Type of Lime ______ Year applied ______ Rate ______ CCE, % ______

General Observations of Field Conditions

Visual Symptoms Can Indicate Plant Disorders

FOR GENERATIONS, the appearance of a plant has been used by scientists, fieldmen, gardeners and farmers to help indicate plant health.

The plant speaks through distress signals. The message may indicate there is simply a shortage of water or there is too much water and, hence, a shortage of air. Or the signals may indicate a disease caused by an organism such as a virus or bacteria.

The plant may be complaining because it is being attacked by nematodes, insects or rodents, either below or above ground. And there may be injuries from frost, hail, wind or field equipment.

If there is an excess of some nutrient, compound or residue that is detrimental to the plant, this condition is also indicated by plant appearance. Finally, if one or more of the essential nutrients are not present in an adequate amount, the plant will also indicate this.

So, visual symptoms tell many more stories than just nutrient deficiencies. It is not always easy to know just what the plant symptom is suggesting.

The purpose of this section is to help find out what is limiting plant growth and, especially, to learn how to tell one symptom from another.

This calls for patience and study and, most of all, experience. It requires knowledge of what a healthy plant should look like. It means using the other diagnostic tools, such as soil testing and plant analyses, to help identify or confirm the visual symptoms.

The modern diagnostician will use soil tests or plant analyses, or both, to help identify the symptom. This is especially necessary when an individual is just beginning to study visual symptoms.

Then, as symptoms are learned, be aware of the hazards in relying solely on this knowledge. Be aware of the possibility of errors. This involves going beyond the field of agronomy and plant nutrition and including the areas of plant diseases, insect damage, weather and environmental factors.

A good diagnostician must be broad in knowledge and meticulous in approach. When all of this is done, it provides a valuable aid for profitable crop production.

There is another very important point to keep in mind. Often a plant will border on deficiency of a nutrient and yet not show any symptoms. This condition is called *hidden hunger*. Here there are no visual symptoms, but the plant is not producing at its capacity.

This is one of the dangers of relying on symptoms. When plants reach the deficiency level where a symptom appears, yield has already been reduced. Too many areas of the world are being farmed in the *hidden hunger* zone.

The following pages describe the general symptoms of factors that limit crop production.

The Plant Nutrients

Sixteen elements are necessary for plant growth. Some of these come from air, some from water, and others from soil or from fertilizers and lime.

They are needed in different amounts, from as much as several million pounds of water to very small traces of some of the elements. A general guide is shown in **Table 1**.

Table 1. Elements essential for plant growth.

Element or material	Chemical symbol	lb/A
Supplied by air and water:		
Hydrogen (as water)	H_2O	2 to 6 million
Oxygen (as oxygen gas)	O_2	5,000-8,000
Carbon (as carbon dioxide)	CO_2	15,000-25,000
Primary or major elements supplied by soil and fertilizers:		
Nitrogen	N	60-300
Phosphorus	P	10-200
Potassium	K	20-400
Secondary elements supplied by soil, fertilizer or lime:		
Calcium	Ca	20-400
Magnesium	Mg	20-400
Sulphur	S	10-200
Micronutrients needed in small amounts:		
Chlorine (chloride)	Cl	5-20
Iron	Fe	1-5
Manganese	Mn	0.5-5
Boron	B	Trace[1]
Zinc	Zn	Trace[1]
Copper	Cu	Trace[1]
Molybdenum	Mo	Trace[1]

[1]Usually measured in parts per million.
These amounts of nutrients are broad approximations and are dependent on the crop being grown and, especially, on the yield of that crop.

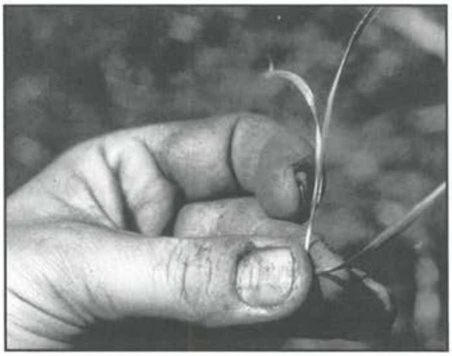
Nutrient Balance

The interrelationship of one element to another is very important. A high quantity of P in the soil or in the plant may result in a deficiency of Zn. A high amount of available K may result in a deficiency of Mg.

And then there is need for more of one element as more of another is added. When more N is added, the need for more K is created because the yield is greater and the plant's needs increase. A farmer might not see K deficiency in one field where only a small amount of N was added; but on an adjoining area where more N was applied, K deficiency may occur.

This whole science of interrelationships, of the effect of one element upon another, is complex. It is mentioned here so the diagnostician can be aware of pitfalls when using visual symptoms.

This does not suggest that we should not learn to use symptoms. But it would warn the user that the symptom simply tells us what the limiting factor is at that time. When this limiting factor is corrected, another may then turn up, so diagnosticians must be aware of these interrelationships. ■



Factors Affecting Symptoms

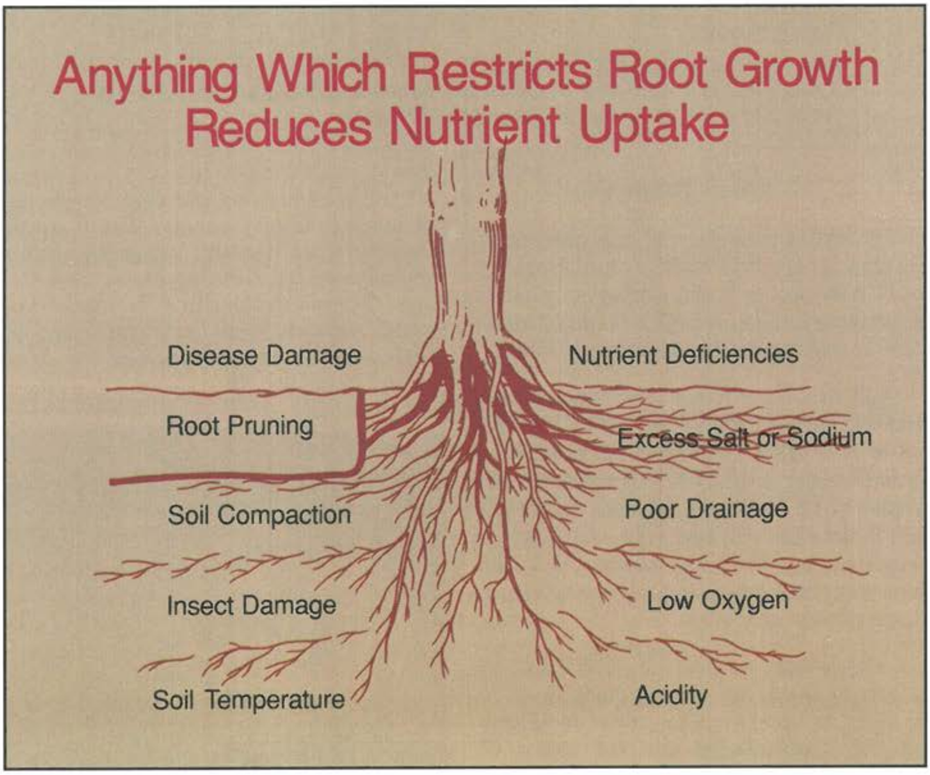
WHY DO SYMPTOMS of a plant nutrient deficiency occur? Because there is not enough of that nutrient present in a form the plant can take up and use.

Often this is simply because the soil is infertile and not enough of that nutrient was added. But there are various other factors that also affect uptake and hence lead to the appearance of symptoms.

Root Zones

Crops differ a great deal in their development of root systems. And even the same crop will vary in the amount of roots developed, depending on the environment and differences in plant genetics. Since some plant nutrients do not move very far in the soil, the extent of the root system will determine whether the plant gets enough of those nutrients. If conditions are such that root growth is rather shallow, plants may show deficiency symptoms even when the soil actually contains a good supply of those nutrients. Dry surface soil conditions may also limit nutrient uptake if most of the available nutrients are in that zone (positional unavailability).

When a deficiency symptom is noted, it is a good practice to examine the roots to see if a restricted root zone may be contributing to the deficiency.



Temperature

Many growers have seen a visual symptom when plants are young, only to see the plant ''grow out'' of this symptom as the season progresses. Often this is caused by the effect of temperature on root growth. If soil and air temperatures are cold, plants grow very slowly, root systems are small and plant nutrient uptake is low.

Also, when air temperatures are too low or too high, photosynthesis and respiration rates are affected. For example, if temperatures are too high at night, respiration continues at a high rate, burning up sugars and limiting the accumulation of carbohydrates.

Acidity or Alkalinity

When a visual symptom is noted, the degree of soil acidity or alkalinity in which the plant is growing should be evaluated. Very often this is closely related to the cause of the symptom.

The solubility and the availability of many plant nutrients depend on soil pH. When the pH value goes above 6.0-6.5, elements such as Fe, Mn, Zn and B decrease in solubility, perhaps to the point where the plants become deficient and show symptoms. And in contrast, when soil pH is too acid (pH below 6.0), Mo becomes less soluble and a deficiency of this element may occur.

Because of the influence of pH on plant nutrient availability, it is essential to learn the liming history where a symptom is observed. Over-liming is easy to do on sandy soils. When these soils are overlimed, deficiency symptoms of Fe, Mn and Zn are likely to appear.

In some parts of the world, soils are not acid, but are naturally alkaline. This is often the case in arid regions where soils are only slightly weathered or where alkaline salts have accumulated. In areas of higher rainfall where there are outcroppings of limestone, the soil pH may be above 7.0. In such soils, deficiency symptoms of Fe, Mn and Zn may be seen.

LIMING is necessary to improve soil pH on acid soils.

Soils in arid regions may also have problems of excess salinity (soluble salt) or Na (black alkali). These problems must be dealt with by establishing drainage, adding amendments if Na is involved and leaching. Plants on such soils grow slowly, appear droughty and may exhibit necrosis of the leaf margins.

Variety — Genetic Factors

Sometimes a deficiency symptom may be noticed in one variety of a crop but not in another. This is not uncommon, but it is often overlooked. Differences in genetic makeup may affect the plant's ability to take up and utilize certain nutrients. One variety may show symptoms of deficiency while another variety growing beside it may not show the symptom at all.

Stage of Maturity

As a plant nears maturity, it shows signs of ''old age.'' These may be a reddening, browning, or leaf tip or edge ''burn.'' But it often looks like a deficiency symptom and may be mistaken for such.

In fact, there is a relationship. As a plant grows older, it may ''run out'' of N or K and therefore may ''mature'' before it has reached its full yield potential. In some crops there is a delicate balance between the amount of N required for full yield and the amount that may be too little or too much. Visual symptoms help us recognize the correct amount. ■

Symptoms Identify Deficiencies

A SYMPTOM will usually occur over an area within a field or even the entire field. It can be related to such properties as poor drainage, sandy conditions, infertile areas, or areas treated differently in the past. If a symptom is found on a single plant, consider disease, injury, or a genetic variation. Also, earlier symptoms are often more useful than those that develop as the plant matures.

It is helpful to keep in mind that some nutrients are relatively ''immobile'' in plants, while others are more ''mobile.''

In general, the symptoms caused by deficiencies of an ''immobile'' nutrient will occur on the upper or younger leaves. The older leaves will remain green and free of symptoms because these ''immobile'' nutrients do not move or translocate from them.

Typically, the **''immobile'' nutrients are Ca, S, Fe, Zn, Cu, B, Mn and Mo.**

In contrast, when there is a deficiency of a ''mobile'' nutrient, the symptoms usually occur in the lower or older leaves of the plant. This is because the ''mobile'' nutrients move out of the older leaves to the younger part of the plant.

Typically, the **''mobile'' nutrients are N, P, K, and Mg.**

However, it should be emphasized that this pattern does not always follow the rule. Plant life is complex and symptoms may appear on the upper and lower leaves. Moisture supply may also enter into the picture. Growth patterns of some varieties can affect the symptoms.

It is also necessary to consider **excesses** of certain elements since these too can produce specific symptoms. The most likely are:

Boron — chlorosis (yellowing) leading to necrosis (dying) of tissue along margins of older leaves;
Sodium — usually no chlorosis, but necrosis of the leaf tips and margins;
Manganese — crinkling of the plant — known as ''crinkle-leaf'';
Aluminum — marginal leaf scorch and stunting.
(Manganese and Al excesses usually occur under very acid conditions.)

For More Information . . .

THERE ARE MANY excellent publications that contain illustrations of plant nutrient deficiency symptoms. Typical of these is the complete and classic book, *Hunger Signs in Crops*. Other books and bulletins published over the past 50 years contain fine illustrations.

In addition, symptoms of plant diseases and insect damage are in print.

Color slides which depict all these symptoms in detail are available from various sources.

The illustrations shown here are simply examples of the type of material that is available. A file of these symptoms can be a valuable resource in diagnosing crop deficiencies.

The Potash & Phosphate Institute (PPI) has available a series of ''Plant Problem Insights'' cards featuring various crop nutrient deficiencies.

Diagnosis of Nutrient Deficiencies in Alfalfa and Wheat (Montana State University Extension Bulletin 43) is a new publication which features photos of alfalfa and wheat with individual nutrient deficiencies.

Individual Nutrient Deficiency Symptoms

NITROGEN. Deficient plants are light green (chlorotic) and growth is stunted. The lower leaves may be affected first, but other leaves follow, with later yellowing and drying and finally shedding of the lower leaves.

In tree crops, the leaves are often small, pale in color and symptoms may appear on any part or all of the plant.

NITROGEN DEFICIENCY symptoms appear on this corn leaf.

NITROGEN DEFICIENCY symptoms on wheat and other small grains appear as chlorosis on older leaves first.

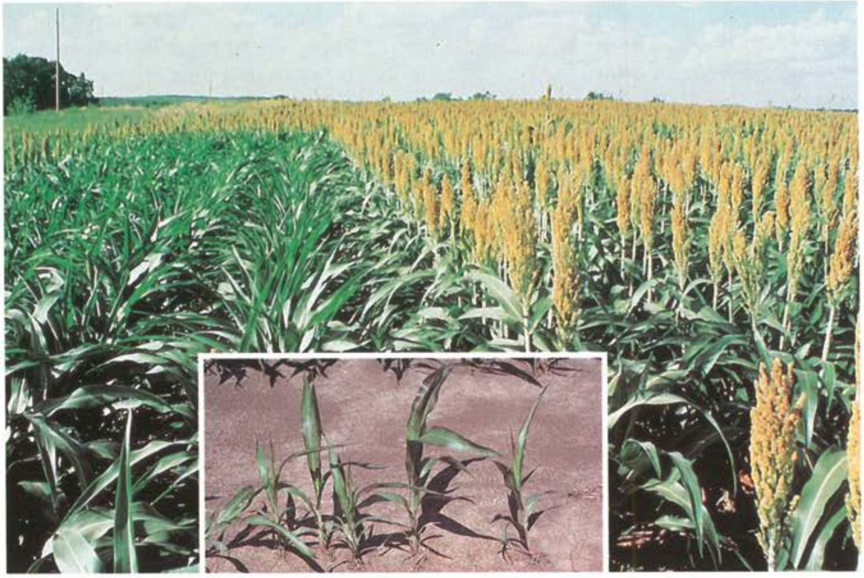
NITROGEN DEFICIENCY symptoms on grain sorghum.

PHOSPHORUS. Deficient plants are often small. Growth is stunted, but in many crops the leaves are darker green than normal. The leaves and sometimes the stems may develop a reddish-purplish cast, especially during early stages of growth (sugar accumulation).

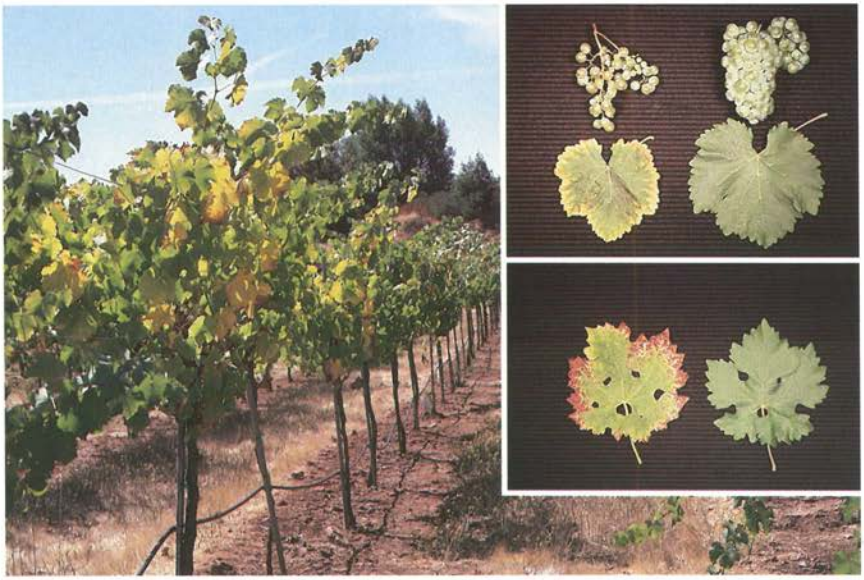
Maturity is delayed and fibrous root development restricted. Petioles, leaves and leaf margins may take an upward direction. Frequently, the only symptom may be smaller plants.

MARGINAL PURPLING of corn leaves is a classic symptom of P deficiency. However, P deficiency can slow growth and delay maturity without purpling. The purpling may also be due to some restriction of root growth, rather than a shortage of P in the soil.

ADEQUATE P fertility in plot at left improved growth, tillering and potential yield of wheat.



EARLY SEASON P deficiency of sorghum shows purple leaves on stunted plants (inset photo). Roots are likely stunted and poorly formed. Late season deficiency causes delayed maturity, poor yield, lower grain quality and elevated grain moisture.



PHOSPHORUS DEFICIENT wine grapes exhibit different symptoms. In white wine varieties, leaf veins remain green and remaining tissue becomes lemon-yellow (field photo and top close-up). In red varieties, interveinal tissue yellows and turns red, producing islands of red tissue surrounded by yellow-green veins (bottom close-up).

POTASSIUM. Scorching or firing along leaf tips and margins is the most common deficiency symptom. This usually appears first on the older leaves. Plants grow slowly, have poorly developed root systems. The stalks are weak and lodging is common.

Seed and fruit are small and shriveled.

Plants show low resistance to disease.

In the case of legumes, the first signs of K deficiency are often small white spots or yellowish dots around the outer edges of the leaves. Later the edges turn yellow and die.

POTASSIUM HUNGER in soybeans begins as firing or scorching on outer edges of leaves. When leaf tissue dies, leaf edges become broken or ragged, with delayed maturity and slow defoliation.

POTASSIUM DEFICIENT CORN ages too fast . . . cells die . . . tissues deteriorate . . . inviting stalk rot. Potassium builds strong stalks and more brace roots . . . helps prevent decaying stalks.

THE FIRST SIGNS of K hunger on alfalfa leaves show up as small white or yellowish dots around the outer edges of the leaves (above). As deficiency increases, these edges turn yellow, become brown, and die.

A SECOND KIND of K deficiency, seen in arid regions, shows a white chlorosis of the alfalfa leaf margin. Low K allows excess Na to enter the plant, producing a Na toxicity or simply a salt burn. Both symptoms may be found in the same field, but on different plants.

IN SOME CROPS, the fruit itself is a large "K sink." Fruit trees, such as prunes shown here, exhibit the most severe K deficiency in heavy-bearing years. Leaves initially turn yellow and develop an irregular marginal burn. Leaves are small and tend to cup upward. In severe cases branches defoliate and die back. Fruit is also small and may have poor color and sunburned spots.

POTASSIUM DEFICIENCY in cotton has been detected with symptoms occurring first at the tops of plants instead of on older, more mature leaves at the bottom. This shift in symptoms has been noted in California and some southern areas of the U.S.

SULPHUR. Deficient plants are pale green and symptoms look very much like N deficiency. The symptoms generally appear first on the upper leaves, while N deficiency generally shows up first on the lower leaves; however, in S deficiency the entire plant can take on a pale green appearance.

Leaves tend to shrivel as the deficiency progresses. Plant stems are thin and woody.

Sulphur deficiencies occur most often on sandy soils low in organic matter and in areas of moderate to heavy rainfall or where irrigation is used. It frequently occurs early in the season. The symptoms may disappear as roots penetrate the subsoil and into areas of higher S content.

SULPHUR DEFICIENCY on wheat occurs where soils are acid, low in organic matter, well-drained or highly leached.

SULPHUR DEFICIENCY on corn may be confused with effects of low N.

MAGNESIUM. Magnesium deficiency symptoms appear first on lower (older) leaves. It appears first as a light, yellowish, faded discoloration with the veins remaining green. In crops such as corn, the leaves are yellowish or very light green striped while veins remain green. In some crops, as the deficiency progresses, a reddish-purplish color develops with green veins.

The pattern is distinct and characteristic and can usually be identified after some experience in observation. It is more likely to occur in acid soils.

MAGNESIUM DEFICIENCY in corn produces light green striping of leaves with green veins, particularly on older leaves.

ALFALFA in this photo shows symptoms of Mg deficiency.

MAGNESIUM DEFICIENCY caused these effects on grapefruit.

CALCIUM. Calcium deficiencies are not often seen in the field because secondary effects, associated with high acidity, limit growth first.

Leaves may be cup-shaped and crinkled, and the terminal buds deteriorate with some breakdown of petioles.

Fruits may break down at the blossom end. Calcium deficiency is known to be associated with "blossom-end rot" in tomatoes and other crops.

CALCIUM DEFICIENCY on corn.

CALCIUM DEFICIENCY on sugar beets.

IRON. Iron deficiency shows up as a very light pale leaf color with veins remaining green, usually first appearing on younger leaves; but severe deficiency may result in the entire plant showing such symptoms.

Iron deficiency can easily be mistaken for Mn and also occurs on high pH soils. The interveinal chlorosis caused by Fe deficiency is often whiter than Mn deficiency symptoms.

Symptoms of Fe deficiency on wheat and other small grains appear as chlorosis on older leaves first.

GRAIN SORGHUM is particularly subject to Fe deficiencies. Younger leaves are most seriously affected, but entire plant may show severe chlorosis. Veins may be darker green than surrounding tissue.

IRON DEFICIENCIES adversely affect the health of apple trees and result in lower fruit yield and quality.

ZINC. Deficiency symptoms appear first on the younger leaves and other plant parts. Crops more likely to show the symptoms are noted here.

In corn, the deficiency is sometimes called "white bud" because the new growth tissue may turn white or light yellow while the leaves show bleached bands, or a striping parallel to the mid-rib.

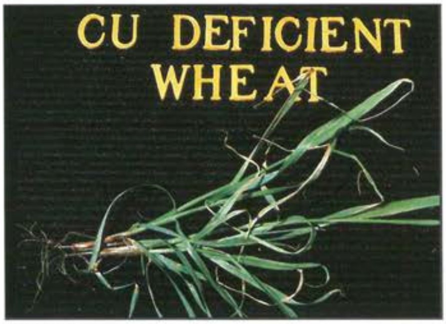
Other symptoms include bronzing of rice, rosette of pecans, "little leaf" of fruit trees, brown spots with yellowing leaf tissues in legumes, and small, pointed, yellow mottled leaves in citrus. Dry beans are very susceptible to Zn deficiency. Plants are severely stunted with severe chlorosis of new leaves.

ZINC DEFICIENCY symptoms in corn appear early in the growing season and affect the youngest leaves. Symptoms may be less severe as the plant matures, but yield will often still be depressed.

ZINC DEFICIENCY symptoms are shown on these leaves of an orange tree.

COPPER. Organic soils are most likely to be Cu deficient, since Cu is fixed in unavailable forms in these soils.

Common symptoms of Cu deficiency include dieback in citrus and blasting of onions and vegetable crops. When vegetable crops show Cu deficiency, the leaves lose turgor and develop a bluish-green shade before becoming chlorotic and curling. The plants may fail to flower, and there is often excessive leaf shedding. Small grains fail to develop heads when Cu is deficient.



COPPER DEFICIENT small grains produce small, grainless heads or may fail to head at all.

COPPER DEFICIENT citrus exhibits dieback of new growth areas and deformed fruit.

MANGANESE. Symptoms first appear in younger leaves, with yellowing between the veins—and sometimes brownish-black specks.

The deficiency is sometimes confused with Mg; however, it usually appears first on the newer (upper) leaves while Mg occurs on older or all leaves. Best way to distinguish is to check soil properties. Manganese deficiency is more likely if the soil pH is higher and in soils higher in organic matter during cool spring months when soils are waterlogged. Liming history is important.

MANGANESE DEFICIENCY in corn produces a yellowing of leaves but veins remain darker green. These symptoms, which appear on younger leaves, are similar to those of Fe deficiency.

MANGANESE DEFICIENCY in celery produces chlorotic leaves with dark green veins at the top of the plant.

BORON. Boron deficiency generally stunts plant growth—the growing point and the lower leaves first.

In many crops, the symptoms of B deficiency are well defined and quite specific, such as crooked and cracked stem in celery, corky core in apples, black heart in beets, hollow heart in peanuts and ringed or banded leaf petioles in cotton.

Alfalfa is especially susceptible to B deficiency, which is shown by rosetting, yellow top, and death of the terminal bud. With experience, this can be distinguished from K deficiency or leafhopper damage. Potassium deficiency symptoms appear on lower leaves.

BORON DEFICIENCY in alfalfa results in a yellowing of younger leaves at the top of the plant.

BORON DEFICIENCY causes the condition called hollow heart in peanuts, shown in the bottom row.

MOLYBDENUM. Molybdenum deficiency symptoms show up as general yellowing and stunting of the plant. In fact, this deficiency can cause N deficiency in legumes because the soil bacteria in legume root nodules must have Mo to help fix N from the air. In vegetables, new growth areas are stunted and die back.

A soil test helps diagnose the problem because Mo becomes more available as the soil pH increases. So liming may often correct the deficiency.

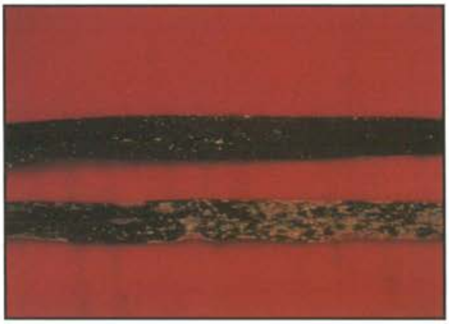
This is not an easy deficiency to identify just from visual symptoms without a soil test or plant analysis and a history of treatment.

MOLYBDENUM DEFICIENCY appears as a yellowing of the plant with severe dieback of new growth areas. Deficiency in cauliflower is shown here.

SOYBEAN RESPONSE to Mo usually occurs where the soil is acid. Seed treatment with Mo can supply that nutrient's requirement for soybeans and soil bacteria in acid soils.

CHLORIDE. Deficiency symptoms on row crops and small grains are not common, but are frequently observed on oil palm and coconut. Deficient palms show high incidence of leaf diseases, droopy leaves and signs of moisture stress during mid-day, frond breakage, cracking of stems and stem-bleeding and greatly reduced numbers of fruits or nuts. Chloride deficient small grains show higher incidence of moisture stress, greater incidence of root, stem, and leaf diseases and reduced yields.

Soil tests can help diagnose Cl deficiency and predict needs for supplemental application. Tissue analyses can also help determine adequacy of Cl in the soil. ■



CHLORIDE DEFICIENCY in wheat has been associated with higher incidence of both root and stem diseases. The wheat leaf at top is from a plant which received the equivalent of 72 lb of Cl/A.

CHLORIDE DEFICIENCY in oil and coconut palm results in higher incidence of leaf disease, broken fronds and greatly diminished fruit production.

Distinguishing Deficiency Symptoms from Other Symptoms

THE NECESSITY for study and experience has been stressed in learning to detect symptoms due to plant nutrient deficiencies. It is especially important to learn to separate these symptoms from other visual symptoms of plant stress or injury.

Herbicide Injury

Herbicides have been a tremendous boost to efficient crop production. Occasionally, herbicides may be misused, resulting in plant injury. This may be mistaken for a nutrient deficiency symptom. The history of field treatment should be reviewed.

Diseases and Insects

Nutrient deficiency symptoms well known to the diagnostician are not easily confused with other signs of plant distress. However, a relatively inexperienced person may have difficulty in deciding if certain symptoms are due to nutrient deficiency, plant disease, moisture stress, excessive heat, water-logging, insects or nematodes. Relying on all available diagnostic tools can help sort out the causative factor.

First, look for insects by examining roots, leaves and stems. Use a small hand lens to look for evidence of plant disease. Take plants to a plant pathologist or an entomologist for verification and specific identification in difficult cases.

General Features

While symptoms differ for different crops, there are some general clues for nutrient deficiencies and some specific symptoms of the individual nutrient deficiencies that can serve as a guide for all crops. A nutrient deficiency should be suspected when these conditions occur:

- Very poor growth at seedling stage
- Plants badly stunted in early growth
- Root growth restricted or abnormal
- Internal discolorations or abnormalities
- Maturity too soon or too late
- Difference in growth from adjacent crops, even without leaf symptoms
- Poor quality crops — appearance, taste, firmness, moisture content
- Specific leaf symptoms that may appear at different times during growth
- Soil tests and plant analyses are very helpful in confirming what is suspected in the field. ■

Soil Tests for Efficient and Profitable Production

SOIL TESTING is an essential tool for the grower using BMPs. It is helpful in monitoring the soil fertility status. When used along with other information, soil tests are also useful guides in arriving at recommendations for efficient use of fertilizer and lime.

Confidence in soil testing must be maintained. Yet, we must avoid creating the impression that soil tests are "miracle workers." The soil test is a helpful diagnostic tool, just like the thermometer or the stethoscope for the doctor. But all such tools require skill plus common sense in their use and interpretation.

Two factors are essential in soil testing: (1) Obtaining representative samples and (2) correlation studies to interpret the results. Problems in these areas are never completely solved. Research continues.

To use soil tests most effectively in modern high yield agriculture, the following points must be recognized:

1. Keep research up to date in high yield age.
Research is needed to determine the plant nutrient level necessary to sustain top profit yields. Field and greenhouse experiments must be conducted continuously to calibrate or standardize soil tests.

Many field research studies have not provided data at high yield levels, and hence, have limited value for correlation. For example, soil tests calibrated for 135 bushels of corn per acre are inadequate when farmers are interested in 200 bushels.

2. Time and method of sampling are important.
While there has been improvement in sampling procedures, one of the on-going problems in soil testing is failure to collect a sample that is truly representative of the conditions that are to be measured.

Scientific studies of sampling techniques point out the possible errors that can result from:

- Too few cores per sample
- Failure to properly divide fields
- Failure to cover the whole area
- Contaminated samples.

Take into account the time and location of sampling, with regard to time and method of fertilizer placement and depth of sampling as related to tillage and rooting patterns.

How often should the soil be sampled? In many areas the suggestion is to check the levels every 2 or 3 years. But on sandy soils, especially where rainfall or irrigation rates are high, it is recommended that samples be taken annually. The same is true if a mobile nutrient form, such as nitrate or chloride, is part of the test.

Also, there is the question of subsoil sampling . . . and drying the sample. Many labs suggest testing the subsoil.

3. How, then, do you get a good soil sample?
The best practice is to carefully follow the instructions of the lab to which the sample is being sent. Sampling according to maps of soil types can provide another management tool which may include varying fertilizer rates according to soil type.

Detailed (grid) sampling is gaining in importance. This allows fertilizer applications to be varied according to changes within the field. This improved management can result in more efficient use of inputs . . . higher yields . . . and higher profits.

4. Lab methods promote accuracy.
Modern lab equipment, refined techniques, and newer methods have been a great help in improving both speed and precision of analyses.

In the past, soil test improvements usually referred to the development of new and better lab tests. There was no point in developing other phases of testing until the accuracy of laboratory tests (detection methods) was assured.

But with the development of precise detection methods for most nutrients, researchers now are more concerned with issues such as:

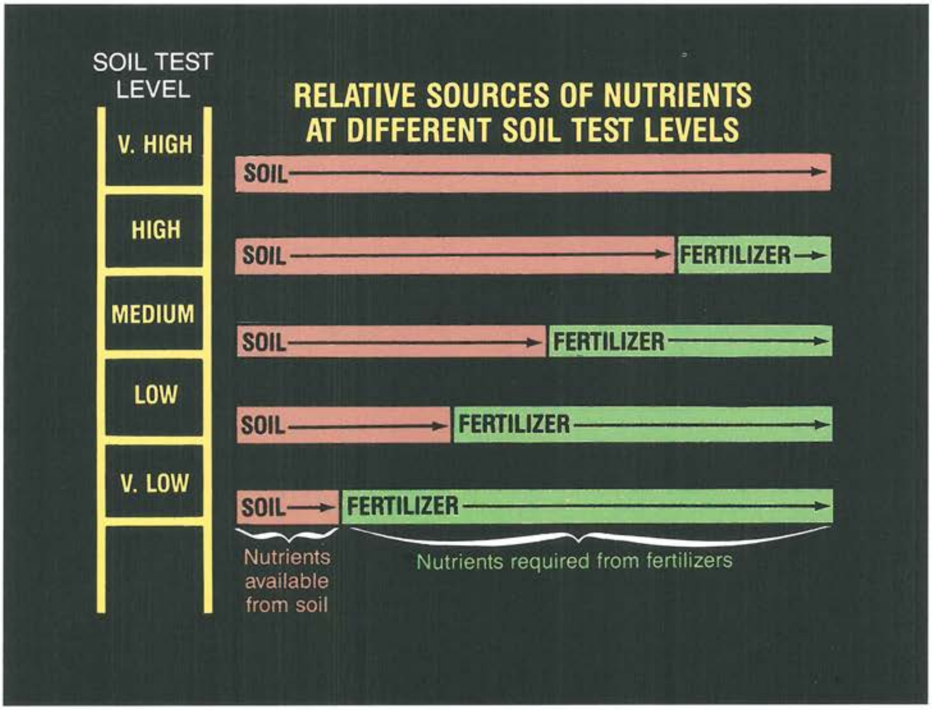
- Extraction procedure — type of extractant, length of time and method of extraction
- Analyses for "sorption" or "fixation" of the various elements. This information indicates the degree of reduction in the availability of an element when it is added to the soil
- Meaning of the figures obtained in the determination.

Sometimes in our efforts to refine a lab procedure we overlook the fact that the results obtained are empirical. Trying to duplicate a plant's uptake of nutrients by using a chemical extraction of the soil is practically impossible. That is why field correlation studies must be the basis for using the results of the extraction to measure soil fertility levels and plant needs.

5. What tests are usually run?
It depends on the lab making the analyses, the nature of the soil and crops to be grown, and what problems are expected to be encountered with the soil or crop.

Virtually all labs in the humid regions run pH, lime requirement (or excess lime), P and K. Many labs also determine organic matter, Ca and Mg and often cation exchange capacity (CEC) and percent base saturation.

Other determinations are optional with some labs. These include sulphate-S, nitrate-N and total N, Cl, and micronutrients such as Zn, Mn, Cu, B and Fe. In arid and semi-arid regions, it may be necessary to run tests for Na and soluble salts.



IF FERTILIZERS ARE USED at "high" and "very high" soil test level, they would be for "starter" purposes only. Soil test levels can become too high and create imbalance among nutrients . . . a good reason to test soils regularly.

6. How about nitrogen tests?
Total N is usually not determined. The information is of limited value in routine soil testing. However, tests for nitrate-N are common in areas of relatively low rainfall and in irrigated areas. Such tests are becoming more common in areas of higher rainfall.

The most reliable tests are generally assumed to be for pH and lime requirement and for extractable nitrate, P, and K. There is more research information behind the interpretation of these tests and, hence, more confidence in them.

7. Other elements.
As yields go up and soil depletion increases, more emphasis is being focused on plant needs for secondary and micronutrients.

Although research on secondary and micronutrients continues, some labs do not feel they have reached the stage where routine soil tests can accurately predict the need for certain micronutrients. In general, however, these tests do provide useful data upon which to base recommendations. It is better to have this information than to be without it.

Additionally, information on soil pH, organic matter content, irrigation water quality, depth of soil profile, soil compaction and liming history may assist in diagnosing micronutrient problems.

8. Lime recommendations.
Many determinations help arrive at soil lime requirements: pH and buffer pH, CEC and percent base saturation, Ca and Mg levels, organic matter and soil texture.

9. What do the numbers mean?
Laboratory analyses can sometimes be misunderstood and create confusion. There are several reasons:

- The soil test value is actually an index. Some labs report the number in terms of amounts of 'available' plant nutrients. Others more properly call the figure extractable plant nutrients. The soil test does not extract the amount of a nutrient that is available, but rather the amount that could become available to the plant.
- Relative fertility levels . . . low, medium, high . . . are calibrated from field experiments involving different rates and combinations of fertilizers. Response may be obtained with one crop but not with another, one year and not another, or at one yield level but not another. Hence, it requires skill and experience in field research to calibrate soil tests with expected response in diverse cropping situations.
- Labs may report numbers in different ways. Nutrients may be reported as:
  pounds per acre (lb/A)
  parts per million (ppm)
  milliequivalents per 100 grams (m.e./100g)

  Parts per million are frequently multiplied by 2 to give pounds per acre, since the average soil weight to a depth of 6-2/3 inches is assumed to be 2 million pounds.
- Labs use different extractants or methods and often report different numbers for the extractable nutrients. This might be confusing, but the number is only an index and must be calibrated with field tests. Thus, a number of 60 lb/A with one extractant could mean the same as one of 100 lb/A with another. Both could be "medium."
- One lab may report the nutrients in the elemental form (such as lb/A P or lb/A K) while another reports the results in terms of the oxide (such as lb/A P_2O_5 or lb/A K_2O). Either is acceptable, but the **numbers** will be different for the same amount of an extracted nutrient. ■

Interpreting Soil Tests

SOIL TESTS are used, along with other background information, to make recommendations designed to eliminate soil fertility as a limiting factor in crop growth. Such recommendations are designed to maximize fertilizer use efficiency and minimize environmental concerns.

Emphasis should be placed on the use of soil tests to monitor soil fertility rather than just to make a recommendation for a particular crop in a particular year. Soil test records can be used to determine if the soil is being depleted, maintained or built-up. Then, for a recommendation, consideration would be given to the crop requirement at the determined soil fertility level.

When interpreting the test, several things should be kept in mind:

1. The probability of a profitable response to fertilization is much greater on a soil that tests low in a given nutrient than on one that tests high.

For instance, agronomists from one university suggest that with a low soil test, there is a 70 to 95 percent chance of getting a yield response. With a high test there is a 10 to 40 percent chance. Another university indicates that with row-applied P and K the probability of response with a high test is 30 to 65 percent.

2. The possibility of a profitable response from fertilizer application at a high level of fertility may occur when other production factors are optimum or when soil and climate conditions impose stress early in the growing season. Similarly, a profitable response on soils of low fertility is not assured when other factors such as climate or management are poor.

3. Interpretation of soil test results and recommendations often becomes a matter of how to improve the fertility status of the soil. How much will be needed to change the soil from low to medium or high in that nutrient? What will be the most economical level at which to maintain the nutrient status of the soil?

4. With top level management practices, yields increase and the probability of a response at any given soil test likewise increases.

There are many questions in soil testing related to high yield levels obtained through BMP systems. Research continues to seek the answers.

Basic Question: What Does the Farmer Want?

Some interpreters use soil tests to see how much fertilizer can profitably be applied. Others use soil tests to see how little fertilizer the farmer can get by with.

Tomorrow's farmer should receive fertilizer recommendations for the maximum economic yield (MEY). At the same time, a soil test gives opportunity for making needed suggestions on crop management inputs that can impact fertilizer use efficiency and crop profitability.

Since farmers today must strive for higher and higher yields, the evaluation of all the factors in the yield equation are required to determine those which can be controlled. Among them is soil fertility. The old philosophy was to test soil and predict the response from addition of a nutrient. But this does not answer the question of today's farmer who wants to keep the soil in shape to produce high yields. Yields should not be limited by a nutrient deficiency or imbalance. It is costly to fall back to an "average" yield and then get response to nutrient application. Rather, soil nutrient levels should be built to an optimum level and maintained there.

The soil test of the future may be used to determine the optimum level of a nutrient required to reach high yields, the amount to be applied to reach this level, and then the amount needed to maintain it. By providing optimum fertility for his crops, the farmer maximizes profit potential and minimizes potential danger to the environment. ■

Making Recommendations Based on Soil Tests

AT ONE TIME, recommendations from soil tests were made only by those who did the chemical tests. Now other individuals make these recommendations after receiving special training.

This offers certain advantages. It can permit recommendations from a person with first-hand knowledge of the farmer and his problems—a person who can follow up on results obtained.

Also, many farmer-businessmen want more than a fertilizer recommendation. They want a complete set of plans to meet a high yield goal. This calls for a complete consulting program—advice on proper variety, cultural practices, time of planting, proper use of pesticides, etc.

Under these circumstances, consulting agencies may be used by farmers to sample their fields prior to planting and to monitor the crop throughout the season. This adds a new dimension to soil tests. The consultant should be well informed and experienced in the use and interpretation of soil tests.

Industry and commercial labs, as well as state labs, are well equipped to run soil tests with precision. The numerical results that one lab reports may differ from that of another lab, but this does not mean that one is correct and the other is not.

As previously presented (page 25), the numerical figure is relative,and its meaning in terms of high, low, or medium depends on the calibration system and also the basis for making recommendations.

Two scientists could recommend different rates of nutrients from the same soil test, depending on many factors such as yield goal, plans to build or deplete present soil fertility level and even the type of farm operator (owner or tenant) for whom the recommendations are being made.

For this reason, the use of computers for making recommendations must be carefully handled. The computer printout should be subject to modification by those who know the past history, the management practices of the farmer, and the many local conditions that are part of yield determination.

It is difficult to visualize a medical doctor making a diagnosis on the basis of an analysis of a blood sample mailed in by a patient. The doctor would want to see the patient, ask questions, get a personal history and use the blood analysis as a diagnostic aid.

Computers have provided tremendous labor savings in data handling, and result in fewer errors in the mechanics of calculating and reporting values. Also, computer storage of soil test values has facilitated annual summaries of soil test data.

The computer is extremely useful, but do not expect it to make quantitative judgment decisions.

Recommendations When Levels Are High

One might ask, "If my soil tests high in a plant nutrient, should I add more?" This depends on what is meant by "high." If it means that there is an abundance of the nutrient present in the available form, then it should not be applied, at least not for the current crop.

Some labs assign the "high" value to a soil nutrient level at which there is little probability that applications of that nutrient will produce a response in any given year. A "very high" rating could mean sufficiency or excess of the nutrient.

At the same time, failure to apply a "very high" nutrient for an extended period will result in a depletion of that nutrient. Also, under some conditions crops will respond profitably to a nutrient even with a high test. For example, on early planted corn the addition of P and/or

K as a row application may produce response on soils testing high or very high.

Often farmers fail to place a value on residual fertility. While immediate return on the fertilizer investment is important, the better farmers are interested in good returns that come from high-yielding, healthy, even-maturing crops.

What Do Soil Tests Mean?

When soil fertility levels and yield levels are low, fertility level is an important limiting factor in crop yields.

When fertility levels and yields are higher and as the better farmers strive for even higher yields and quality, other factors become increasingly important along with fertility. The goal is to build soil productivity, as well as fertility.

Long-term fertility trials are essential if soil test calibrations are to be meaningful. Many farmers operate land on a long-term basis but it is also important to consider short-term lease implications in making recommendations.

Soil tests are very useful diagnostic tools. And that is just what they are—tools. To consider a soil test as infallible or as an exact predictor of nutrient needs is a mistake.

The fact is, the value of the soil test itself is seldom questioned. It is in the interpretation of the tests where the differences occur.

In Summary

- A soil test measures the relative soil fertility level.
- High-yield research must determine the fertility of the entire soil profile at which most profitable yields are consistently produced.
- When interpreting a soil test, the goal should be to maintain the plant nutrients at that level where the supply will not be a limiting factor at any growth stage from germination to maturity.
- For soil testing to be even more helpful and more reliable in high yield agriculture, there must be more long-term research at high yield levels. Also, more attention must be devoted to proper sampling time and techniques.
- Soil tests are important in planning a long time fertility program. Sampling periodically and maintaining records of fertility levels, yields and all management practices is a must.
- Soil testing is a basic tool for growers striving to use BMPs . . . for sustained profitability and environmental protection. ■

Final Note on Soil Testing

IN THIS DISCUSSION, no attempt has been made to present the theories behind various extraction procedures (or philosophical interpretations). Nor are there any specific instructions on soil sampling or analysis.

There are many excellent soil testing laboratories throughout North America and the world. These include state and provincial supported laboratories and those operated by private industry. They offer literature which describes their services in detail.

Select a soil testing lab on the basis of the lab's reputation and follow all the instructions of that lab. Continue to monitor soil test levels over the years. ■

Plant Analysis

PLANT ANALYSIS has been used as a diagnostic tool for many years. It is based on the concept that the concentration of an essential element in a plant or part of the plant indicates the soil's ability to supply that nutrient.

Thus, nutrient concentrations in plants are assumed to be directly related to the quantity of that nutrient in the soil that is available to the plant. A second assumption is that, up to a certain critical point, the content of a nutrient in the plant is directly related to yield.

Plant analysis usually refers to the quantitative analysis for the total amount of essential elements in plant tissue. It should be distinguished from rapid (qualitative) plant tissue tests, which may be made in the field.

Plant analysis and soil testing go hand in hand.

Reasons for Using Plant Analysis

1. **To diagnose or confirm diagnoses of visible symptoms.** Nutrient deficiencies are often difficult to identify because a number of different factors may cause similar symptoms. Often, analyses are used to compare normal and abnormal plants.

2. **To identify "hidden hunger."** Sometimes a plant may be suffering from a nutrient deficiency but show no symptoms. A plant analysis looks beyond the appearance of a crop.

3. **To indicate if applied nutrients entered the plant.** If no response was obtained to applied nutrients it might be concluded that the nutrients were not lacking. However, such factors as pests, unfavorable placement, soil chemical properties or moisture stress might have prevented uptake.

4. **To indicate interactions or antagonism among nutrients.** Sometimes the addition of one nutrient will affect the amount of another taken up by the plant. For example, Zn uptake may be reduced with high rates of P application.

5. **To study trends during the year or over the years.** Periodic sampling during the season may help to determine if a nutrient is becoming deficient. Sampling a crop over the years monitors trends in the levels of fertility in the soil. Many of the more common nutrient deficiencies are the result of long-term improper lime and fertilizer practices. Plant nutrient deficiencies or excesses can be detected before they appear as visual symptoms or reduce yields and quality.

6. **To suggest additional tests or studies to identify problems in a field.** Plant analysis can be useful in locating areas for plant nutrition studies.

Calibration with Yield and Nutrient Supply in the Soil

Of utmost importance is how plant analyses relate to available nutrient levels in the soil and/or to nutrients applied. Studies involving application rates of a nutrient at various levels of that nutrient in the soil are essential in defining the relationship. While many such studies have been conducted, yield levels have often been relatively low by today's standards. There is an urgent need for carefully controlled experiments at modern yield levels and up to the maximum yield for a given soil and environmental situation.

Yield level may have a distinct effect on what is considered to be an adequate level of a nutrient in the plant. A prime example is K in alfalfa. A number of years ago, 1.25 percent K was considered adequate. As yields moved up, the value was changed to 1.5, 1.75, 2.0 and 2.5 percent. Now some think 3.0 percent K or more is needed for sustained high yields and quality and to maintain the alfalfa stand. Examples could be cited for other crops.

At a low yield level, factors other than plant nutrients may be limiting, and the content of a nutrient in the plant may mean little.

Critical level. Critical level has been determined for most nutrients in many plants. It is defined as the content of an element below which crop yield or performance is decreased below optimum. In some instances it is considered to be the point giving 90 to 95 percent of maximum yield. For example, in corn, around 3 percent N, 0.3 percent P and 2 percent K in the ear leaf at silking have been considered critical levels. However, it is difficult to choose a given level because many factors affect whether a given content is sufficient or insufficient. Top profit farmers may not be satisfied with 90 to 95 percent of maximum yield.

Ranges of concentration. Nutrient concentration ranges have been developed and labelled as deficient, low, sufficient (or adequate), high and toxic for many crops. This concept is frequently more useful than the absolute critical levels. When using plant analysis as a diagnostic tool, an excessively high amount of an element may be as important as a deficiency.

Balance of nutrients. Nutrient balance is a different approach in that ratios of nutrients rather than independent concentrations are evaluated. This approach has been refined in recent years and is usually referred to as the "Diagnosis and Recommendation Integrated System" (DRIS). ■

Factors Affecting Nutrient Concentrations in Plants

THE SOIL TEST LEVEL and amounts of nutrients added in fertilizers, manures, residues and soil amendments are key factors in nutrient availability. However, the concentration of a nutrient within a plant is the integrated value of all the factors that interacted to affect plant growth. Considering the multiplicity of factors that influence growth and resulting crop yields, it is surprising that plant analysis relationships hold as well as they do. Some of those factors are discussed in the following paragraphs.

Soil moisture. At low soil moisture it is more difficult for plants to absorb nutrients so the content of a nutrient will be lower. It is important to add enough nutrients to insure against seasonal variations in moisture and other unfavorable environmental conditions.

Temperature. Low temperature reduces uptake of a number of elements including N, P, K, S, Mg, B and Zn. In cooler climates it has been found that a higher soil test level or rate of applied nutrients must be used to achieve plant nutrient concentrations comparable to those found in warmer climates. Under cooler conditions root growth is slower and plant uptake processes are slowed. Also, release of such elements as N, P and S from organic matter through mineralization is slowed when temperatures are low.

Soil pH. Soil acidity or alkalinity influences the availability of many nutrients. For example, a higher pH tends to lower Fe, Al, Zn, Mn and B availability, but increases Mo availability in plants. A lower pH makes it more difficult for the plant to absorb Mg and P, but more Mn, Fe and Al are absorbed.

Tillage and placement. Conservation tillage practices may cause a reduced uptake of nutrients, including P and K. This is due in part to positional availability because much of the fertilizer is broadcast and remains on or near the surface. Band placement of nutrients near the seed or deeper in the soil improves uptake by the plant.

Side-band placement is effective for increasing uptake of plant nutrients in early growth stages and may influence yield.

Compaction. Soil compaction can have major effects on plants' abilities to absorb nutrients. Compaction reduces the amount of oxygen in the soil, root energy production processes are slowed and, consequently nutrient absorption is slow. Concentrating moderate amounts of readily available nutrients in starter fertilizer close to the seedling plant can help overcome these problems.

Growth and yield responses to starter fertilizers even on high testing soils may be partially due to higher concentrations of nutrients helping to overcome plants' diminished abilities to take up nutrients under compacted conditions. Data in **Table 1** indicate how starter K can help overcome effects of compaction. Note that the effects of K were greater as compaction increased.

Table 1. Starter K can help offset effects of compaction in corn production.

Soil compaction, tons	Corn yield, bu/A		Starter K response, bu/A
	No K	45 lb K_2O/A	
< 5	132	162	30
9	114	152	38
19	111	159	48

Oshkosh, WI, 1985—Bundy, Univ. of Wisconsin
Soil test K: 102 ppm (High)

Hybrid or variety. The yield of a crop is the result of genetic capability and environmental factors. Hybrids or varieties vary greatly in their yield capability. For example, in an experiment in New Jersey one corn hybrid yielded 312 bu/A and another 227 bu/A under exactly the same environment. Obviously, the total nutrient uptake would be much different between the two.

Varieties or hybrids may vary widely in their nutrient requirements and responses to environmental conditions. For instance, K studies have demonstrated significantly different corn hybrid responses to K knifed into the ridge for ridge-till corn (**Figure 1**). Differences in corn hybrid responses to starter P have also been documented. Corn hybrid differences in N uptake patterns, time of N application and availability of ammonium-N for the plants further emphasize genetic effects on nutritional requirements. More information must be collected to determine differences in critical or sufficiency levels of nutrients for specific varieties and hybrids.

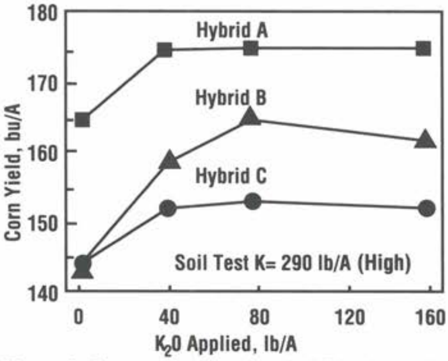


Figure 1. Corn response to banded K in ridge-till. Rehm, Univ. of Minnesota

Interactions. High concentrations of one element may cause imbalances or deficiencies of other elements. The relationship between P and Zn is one example. A high amount of available P may reduce the amount of Zn absorbed by a plant. Under a marginal Mg supply in the soil, an application of K may reduce the Mg uptake to the point of deficiency in the plant. The concentration of K in the plant may be reduced by a high rate of ammonia N.

Stages of growth. The concentration of an element considered to be adequate changes as the plant grows and matures. Hence, it is important that plants be sampled at comparable and recognizable growth stages. ■

Soil Testing

"Don't let what you can't do keep you from doing what you can do."

Fifty years ago I was Director of the Soil Testing Division in North Carolina. It was in the State Department of Agriculture. Top administrators in the College of Agriculture at North Carolina State University would have no part of this gimmick. County agents were directed not to use it.

Why? There were things that soil testing couldn't do, and that kept them from using it for what it *could* do.

We have a more open mind today. Yes, there are those who misuse it. Yes, we do need more good calibration research. Yes, there are pitfalls in proper sampling. But that shouldn't keep us from making good use of an excellent diagnostic tool.

With emphasis on the environment, the diagnostic approach will assume even greater importance. Wherever chemicals are applied, their use will be monitored. To be ready for this, more support for research is essential. And education must be expanded on the value as well as the limitations of all these tools.

Soil and plant scientists are experts in this field. They must assume the leadership and be heard.

— J. Fielding Reed

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