Diagnosing Crop Nutrient Deficiencies in the Field

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Introduction

The old adage 'You can't fix a problem if you don't know you have one' underpins the basic science of diagnosing plant nutrient deficiencies. For years, farmers and scientists have worked together to identify a set of visual clues that can be used to determine nutrient deficiencies in a variety of agronomic crops. These clues and symptoms can be extremely useful, especially when soil and plant tissue testing methods are neither feasible nor available.

Ensuring that your crops are supplied with adequate fertility is a difficult yet rewarding endeavor. However, you will face many frustrations if you wrongly assume that plants have access to each and every nutrient. Developing the ability to identify crop nutrient deficiencies will help to address problems in the field, and will also help to avoid costly attempts to correct the wrong problems. Nutrient deficiencies are often and easily mistaken for insect damage, diseased crops, nematode problems, and/or other abiotic stress factors (Figure 1).

A few simple tools and a basic understanding of plants' nutritional needs will equip you to recognize specific crop nutrient deficiencies, and to distinguish their symptoms from a variety of other detrimental symptoms.

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Figure 1: Various crop nutrient defi ciencies and their symptoms: a. Nitrogen defi ciency (IPNI, 2016); b. micronutrient defi ciency (iron); c. phosphorus defi ciency (IPNI, 2016); d. micronutrient defi ciency in citrus (FFTC, 2003).

Which Nutrients do Plants Require?

Seventeen chemical elements are essential to the growth of a plant (Table 1). An element is considered essential only ifit is necessary for a plant to complete its life cycle, and no other element can substitute for it (IPNI, 2006).

Nutrients Essential for Plant Growth			
Nutrients from Atmosphere & Water	Nutrients from Soil & Amendments *(Soil, Compost, Manure, Fertilizer, Organic Matter...)*		
Structural Elements	Primary Nutrients	Secondary Nutrients	Micronutrients
Carbon (C)	Nitrogen (N)	Calcium (Ca)	Boron (B)
Hydrogen (H)	Phosphorous (P)	Magnesium (Mg)	Chlorine (Cl)
Oxygen (O)	Potassium (K)	Sulfur (S)	Copper (Cu)
			Iron (Fe)
			Manganese (Mn)
			Molybdenum (Mo)
			Nickel (Ni)
			Zinc (Zn)
*Elements listed on the left are taken up in the highest quantities; those on the far right are needed only in minute quantities.			

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Table 1: Essential elements needed for plant growth (IPNI, 2006).

Most of these essential elements are found in the soil. Carbon, hydrogen, and oxygen are obtained from the atmosphere and water during photosynthesis. If any one of these 17 elements is deficient or limited, plant growth will be reduced and plants may not achieve their genetic yield potential—even if all other 16 essential elements are fully available.

Understanding Your Environment is the First Step

A basic understanding of your land—including regional geography, soil type, cropping history, and recent management practices—can help you to identify nutrient deficiencies in your crops, and to distinguish deficiency symptoms from those that result from pests or disease.

pH

Understanding the pH of your soil, or at least the general level of acidity or alkalinity, can be very helpful when trying to identify nutrient deficiencies. Even if you do not formally test the pH, knowledge of your regional geography, soil type, cropping history, and recent management practices might give you a good general idea. Most plants thrive in soils with a pH hovering near neutral (7), and actually perform best when pH is between 5.5 and 6.6; slightly acidic soils are most likely to have all of the seventeen essential elements adequately available for a given crop (Figure 2).

When soils become too acidic, many macronutrients become 'unavailable' or 'bound-up' and can no longer be taken up by the plant. The opposite tends to be true for the micronutrients; they are available in acidic soils but less so in more alkaline soils. Knowing this, and knowing your soil pH, can help you to more easily narrow down your options when diagnosing a deficiency.

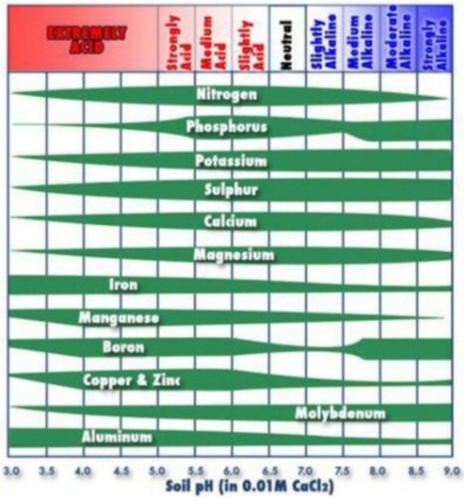

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Figure 2: Nutrient availability in soils of diff ering pH levels (Goldy, 2011). Aluminum is included, because it becomes available to plants in highly acidic soil (which can cause aluminum toxicity).

Numerous factors together determine your soil pH. However, certain basic geographic trends also impact soil acidity and alkalinity. Generally speaking, soils in humid climates tend to be acidic, while soils in arid regions tend to be alkaline. (Figure 3).

Basic Nutrient Deficiency Terminology

If you are able to distinguish between various symptoms, you will be better able to understand and differentiate between individual nutrient deficiencies. Below are common terms used to describe nutrient deficiency symptoms in plants. The terms can be used to describe individual leaves or to describe symptoms aff ecting the plant as a whole.

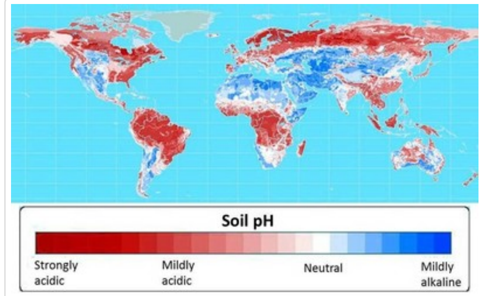

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Figure 3: A world map showing soil pH (Nelson, 1998).

Chlorosis: a general yellowing or whitening of the plant tissue; a lack of chlorophyll (See Figure 1b).

Necrosis: death of plant tissue; usually begins with the yellowing of plant tissue, eventually browning and then death (Figure 4b and 4d).

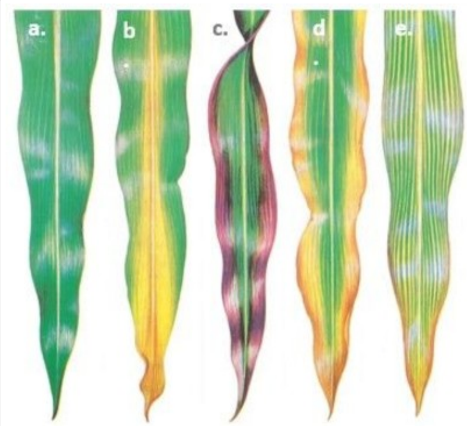

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Figure 4: Healthy maize compared to maize with various nutrient deficiencies: a. healthy; b. nitrogen deficiency (necrosis appears in a v-shaped pattern from the leaf tip); c. phosphorus deficiency (purpling along leaf edges); d. potassium deficiency (necrosis and scorching along leaf edges); e. magnesium deficiency (interveinal chlorosis) (Berger, 1954).

Interveinal Chlorosis: only plant tissue between the veins of the leaves exhibit chlorotic symptoms (Figure 4e).

Burning or Scorching: severe localized yellowing or browning, exhibiting a scorched appearance (Figure 4d).

Mottling: a spotted, irregular, or inconsistent pattern.

Diagnosing Nutrient Deficiencies in Crops

Within a plant, some nutrients are mobile (i.e. can be moved), while others are immobile (i.e. cannot be moved). Generally speaking, macronutrients tend to be mobile, while micronutrients tend to be immobile. The location of symptoms on a plant plays an important role in helping us narrow down and identify which specific nutrient deficiency the plant is exhibiting.

A plant can relocate mobile nutrients, usually moving them from the older leaves to the area of new growth. Plants do this to ensure that growth continues to happen, typically when a certain nutrient is deficient. In this case, deficiency symptoms will appear in the older growth, or lower portion of the crop (Figure 1c).

Immobile nutrients are fi xed and cannot be relocated within the plant. These nutrients are usually incorporated into the structural components of plants. For example, calcium is a component of cell walls, and remain in place (IPNI, 2006). Deficiency symptoms of immobile nutrients will typically and initially be located in the new growth, near the top of the plant (Figures 1b and 1d).

Figure 5 illustrates which of the essential elements are mobile (can be translocated), and will therefore have symptoms initially appearing in older leaves, and those which are immobile (non-translocated), with symptoms initially appearing in the new growth.

While symptoms for various nutrient deficiencies will tend to begin in the aforementioned plant locations, they can progress throughout the entire plant if the deficiency is severe. deficiency symptoms can also mask one another, when the deficiency symptoms of one nutrient will be more visibly obvious than those of a concurrent but less severe deficiency.

Breaking Symptoms Down by Individual Nutrient deficiency

It is relatively simple to distinguish between nutrient deficiencies that appear on older growth and those that appear on new growth; as mentioned previously, the former tend to indicate macronutrient deficiency and the latter point to micronutrient deficiency. This is a helpful start, but we really want to narrow down to the individual nutrient that is lacking.

To narrow down the diagnosis, we will need information regarding the location of symptoms on the plant, but also the pattern and location of symptoms on the individual leaf.

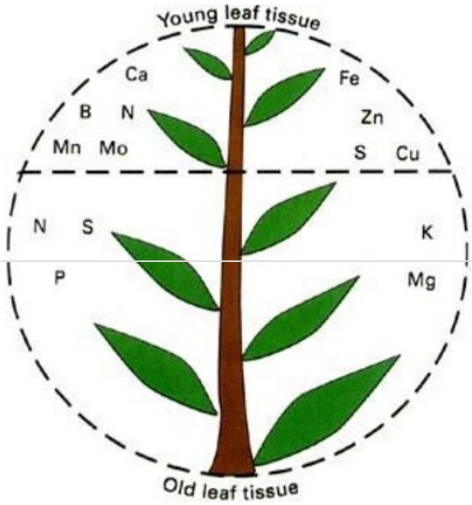

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Figure 5: Locations of nutrient deficiency symptoms in plants. Mobile nutrients (listed at the bottom) will show symptoms on the lower part of the plant, while immobile nutrients (listed at the top) will show symptoms on the upper part of the plant (IPNI, 2016)

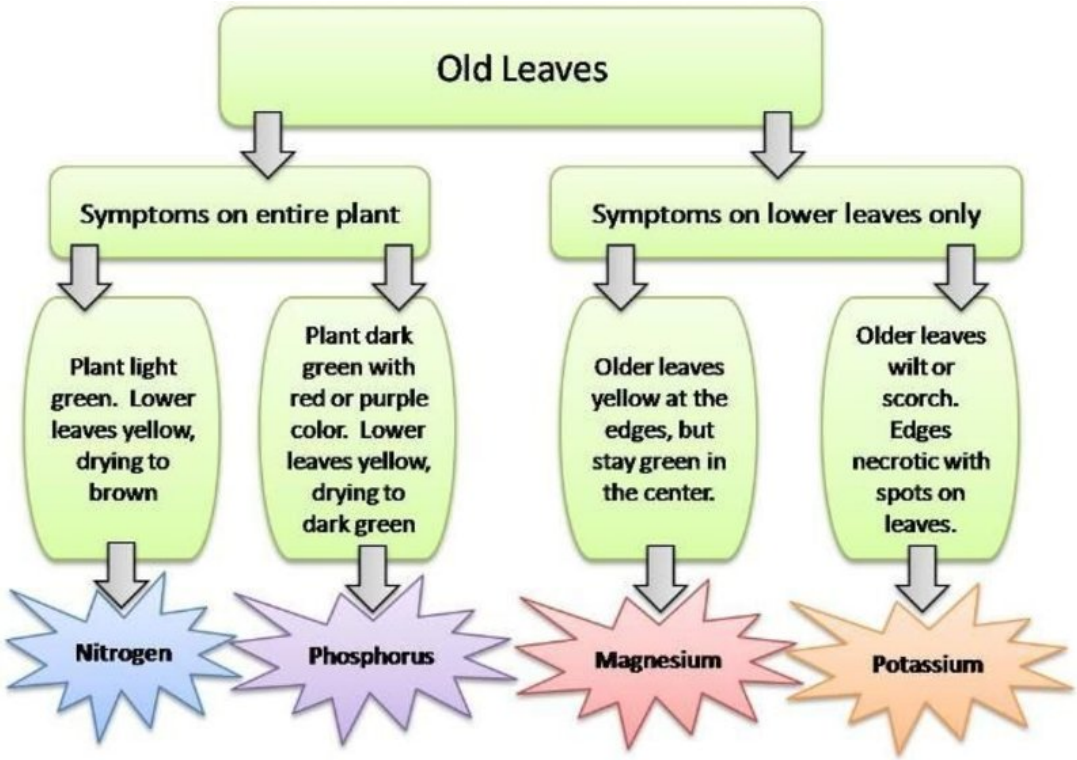

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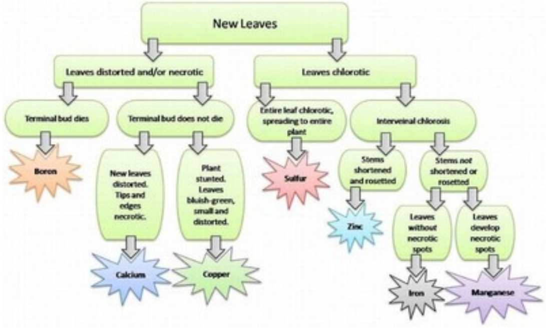
Figure 6: Flow chart for diagnosis of basic nutrient deficiencies (IFAS, 2012).

Figure 6 provides a flow chart to help distinguish between individual nutrient deficiencies. Use of the diagram requires detailed attention to plant stress symptoms. In addition to location on the plant as a whole, you will need to distinguish between symptoms such as necrosis and chlorosis. You will also need to identify the symptom location on a particular leaf. For example, is the necrosis on the edges of the leaf (as in the case of potassium deficiency; Figure 4d), or is it chlorosis between the veins (as in the case of magnesium



(/resources/9af5269b-ee33-49ac-bc09-4405c7785e6a)deficiency; Figure 4e)? This kind of distinction, relatively simple to make given a bit of practice, will lead to a more accurate diagnosis.

Many detailed and thorough resources have been compiled on the topic ofidentifying plant nutrient deficiencies by their symptoms. Here are some particularly good ones: Guide to Symptoms of Plant Nutrient Deficiencies (http://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1106.pdf)- University of Arizona Plant Nutrient Functions and deficiency and Toxicity Symptoms (http://landresources.montana.edu/nm/documents/NM9.pdf)- Montana State University Crop Nutrient deficiency Image Collection (https://store.ipni.net/products/crop-nutrient-deficiency-image-collection) - Available for purchase through the International Plant Nutrition Institute (IPNI)

Introducing IPNI's Smartphone App for Nutrient Deficiency Diagnosis

For the technologically inclined, a smartphone application is available from the International Plant Nutrient Institute (IPNI). The app includes a small set of digital images depicting individual nutrient deficiencies (Figure 7).

IPNI INTERNATIONAL PLANT NUTRITION INSTITUTE

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The app also provides a description of nutrient deficiency symptoms by individual nutrient and for 14 of the major agronomic crops worldwide. The crops were chosen to represent a diverse range of species, even if only 14 are specifically listed. For example, pearl millet is not listed in the app, but its symptoms will be similar to those of maize or sorghum, which have a similar physiology.

Disclaimer: This smartphone app does not measure deficiencies by itself, but rather serves as a useful tool in the hands of someone attempting to identify nutrient deficiencies.

This Plant Images app is available in multiple languages from the Apple App Store (search for "Crop Nutrient deficiency Photo Library" or "International Plant Nutrition Institute"). Information is also found at http://www.ipni.net/ndapp (http://www.ipni.net/ndapp).

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Figure 7: Images of the IPNI mobile application

Next Steps, Once a Deficiency is Identified

Once you have correctly identifi ed a nutrient deficiency in your crop, you will want to take steps to resolve the problem. Will supplying the appropriate nutrient solve the issue, or might the deficiency be a symptom of a greater problem?

More often than not, complex factors are at play when crops exhibit deficiencies. Some can be easily corrected, but others might take years to rectify. Below are some potential issues that commonly result in specific crop nutrient deficiencies.

pH – As previously mentioned, the pH of soil plays an integral role in determining which nutrients are available for uptake by a plant. If soil is too acidic, the nutrients N, P, K, S, Ca, and Mg will be less available. In alkaline soils, Fe, Mn, B, Cu, and Zn will be less available (Figure 2). If you have identified some of these as deficient, you might have a pH problem (but you will want to test the pH to be sure). To adjust pH, agricultural lime can be added to acidic soils, and sulfur to alkaline soils. Further readings on this particular topic are available at ECHOcommunity.org (http://www.echocommunity.org); for example, the documents Acid Soils of the Tropics (https://c.ymcdn.com/sites/echocommunity.site-ym.com/resource/collection/e66cdfdb-0a0d-4dde-8ab1-74d9d8c3edd4/Acid_Soils_of_the_Tropics_[Web_Format].pdf?hhSearchTerms=%22Acid+and+Soils+and+Tropics%22) and Biochar (https://c.ymcdn.com/sites/echocommunity.site-ym.com/resource/collection/49b3d109-0de9-458e-915b-11aaf1a67e20/TN_75_Biochar--An_Organic_House_for_Soil_Microbes.pdf?hhSearchTerms=%22biochar%22) might provide more practical and context-specific solutions.

Flooding or Poor Drainage – Nitrogen deficiency symptoms often occur in low-lying areas of a fi eld, or areas with poor drainage. When soils are inundated with water, plant-available nitrate (NO3) is leached (drained away) and/or denitrifi ed (Sawyer, 2007). Denitrification occurs when soil bacteria utilize nitrogen compounds in place of oxygen (which is limited by fl ooding); the compounds are subsequently broken down and the nitrogen is released back into the atmosphere in the form of nitrogen gas (N2). Denitrification can leave large areas deficient of nitrogen during and after flooding (Figure 8a).

Drought Stress – Drought stress symptoms can also be confused with nutrient deficiency symptoms. In both cases, plants exhibit a similar overall stunting. However, drought stress symptoms can be distinguished initially by the wilting and then curling of leaves, followed by the scorching of leaf tips. Many plant nutrients become unavailable to a plant when there is little water to solubilize them into a form that can be taken up by plants.

Other Symptoms Easily Confused with Nutrient Deficiencies

Disease Damage – Nutrient deficiency symptoms are often mistaken for viral, bacterial, or fungal diseases, because each of these result in a yellowing and necrosis of leaves. Nutrient deficiency can typically be distinguished from pest damage and disease by its symmetry. Disease symptoms are mottled, blotchy, or unevenly positioned on the plant or leaf (Figure 8c), while nutrient deficiencies tend to be symmetrical and evenly dispersed in the plant or leaf.

Nematode Damage – Plants aff ected by nematodes show stress symptoms easily confused with a variety of nutrient deficiency symptoms. Nematode damage is especially easy to confuse with nitrogen deficiency from flooding and denitrification. The former can typically be distinguished by the presence of symptoms outside of low-lying areas (not a drainage issue) and wilting on only the tops of plants (Figure 8d). If nematodes are suspected, pull up a few plants and examine the roots for “knots”; if possible, you can have a sample sent to a local lab for accurate identification. Correctly identifying the presence of nematodes in your field can be difficult, and should be confirmed with a microscope.

Herbicide Drift – Herbicide drift can occur when herbicides are applied on a windy day, or in close proximity with other crops. If the herbicide doesn’t kill the unintended target crop, it can cause damage, leaving symptoms that can be easily confused with nutrient deficiency symptoms. Again, this can usually be distinguished by an irregularity of chlorosis or necrosis, rather than a symmetrical pattern. Depending on the chemical, it can leave symptoms of severe chlorosis (Figure 8b) or symptoms of ‘scorching’ on leaf tips. The symptoms will come on very suddenly, most likely within 24 to 48 hours of an herbicide application. Plants have the ability to outgrow smaller levels of damage due to herbicides.

Conclusion

Diagnosing crop nutrient deficiencies is not an exact science. However, these relatively simple diagnostic tools can help you to improve the productivity and health of your soils. They can help you avoid issues of hidden hunger in your crops, and may alert you to greater issues present in your location. These on-farm diagnostic tools can be especially useful for those working in areas where soil and plant tissue-testing facilities are either unavailable or unaffordable.

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