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Iron Deficiency of Hydroponic Leafy Greens and Herbs

Iron deficiency is one of the most common nutrient disorders in hydroponic crops. The general symptoms are yellowing between the veins of young leaves. This article will describe the symptoms, causes, and prevention of iron deficiency in hydroponic greens and herbs.

Iron is an essential element required by plants for synthesis of chlorophyll and for energy transfer in photosynthesis and other processes. Because iron is needed by the plant in relatively small amounts (Table 1) it is considered a micronutrient. Unlike nitrogen and several other macronutrients, iron is relatively phloem immobile. This means that once iron is taken up by the plant and deposited in leaves, it can no longer be moved around within the plant. Because of this, if iron becomes unavailable it cannot be scavenged from older leaves, instead new leaves will exhibit the symptoms.

Figure 1. Lettuce with iron deficiency, notice young/immature leaves are affected.

Symptoms

Symptoms of iron deficiency are present initially on young/immature leaves and appear as interveinal chlorosis (Fig. 1).

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Figure 2. Basil exhibiting sustained iron deficiency. Note that both young and recently mature leaves exhibit yellowing between the veins, whereas mature leaf (by hand) is uniformly green.

That is veins stay green but the region between veins turns yellow. The symptoms are typically uniform across the leaf. The youngest leaves may appear uniformly chlorotic. If iron deficient condition continue, the symptoms progress so that recently mature leaves also exhibit interveinal chlorosis (Fig. 2). Under extreme iron deficiency, new leaves can appear almost white. At

Table 1. Average tissue analysis range of healthy greenhouse butterhead lettuce. Tissue samples taken from most recently mature leaves. (From H.A. Mills and J. Benton Jones, Jr. 1996. Plant Analysis Handbook II. MicroMacro Publishing, Inc.

Macronutrients (%)		Micronutrients (ppm)	
N	4.20-5.60	Fe	168-223
P	0.62-0.77	Mn	55-110
K	7.82-13.68	B	32-43
Ca	0.80-1.20	Cu	6-16
Mg	0.24-0.73	Zn	33-196
S	0.26-0.32	Mo	0.29-0.58

Cornell we conducted experiments on hydroponic lettuce, basil, arugula, and spinach whereby iron was removed from the nutrient solution recipe. Symptoms of iron deficiency were visible within 10 days for lettuce (Fig. 3) and 14-21 days for arugula (Fig. 4) and basil. For arugula, plants with severe iron deficiency, the plants also exhibited numerous necrotic spots between veins of young leaves (Fig. 5). Spinach did not exhibit visible symptoms of iron deficiency even after 28 days without iron in the nutrient solution.

The symptoms of iron deficiency can look similar to other deficiencies, especially magnesium and manganese. In the case of magnesium, symptoms are also uniform interveinal chlorosis, however lower/mature leaves are affected not immature leaves. This is because magnesium is phloem mobile. That is magnesium can be scavenged from old leaves and transported to new growth. In the case of manganese deficiency, symptoms are, like iron, also interveinal chlorosis of young/upper leaves. However, small scattered necrotic spots are more common with manganese deficiency. Because of look-alike disorders one must pay special attention to

Figure 2. Young lettuce leaves exhibiting interveinal chlorosis, 10 days after iron was discontinued from the nutrient solution.

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where the symptoms occur and their pattern of development. In addition, a commercial nutrient analysis laboratory can be used to assess nutrient status of the hydroponic nutrient solution and plant tissue and further help confirm the disorder.

Causes

Iron deficiency arises because either there is not enough iron in the hydroponic nutrient solution or because solution pH is too high and iron is unavailable for plant roots to absorb. Iron is typically supplied in the range of 1 to 3 ppm in the hydroponic nutrient solution. The nutrient solution pH impacts solubility of nutrients. In the case of iron, high pH (such as > 6.5) reduces availability of iron through the joint processes of oxidation (whereby Fe^{2+} increasingly converts to the form Fe^{3+}, which is less available to roots) and precipitation (whereby Fe combines with another ion, for example carbonate CO_3^{2-} or phosphate HPO_4^{2-}, and forms an insoluble complex). Most often the cause of iron deficiency is due to high nutrient solution pH rather than lack of iron in the hydroponic nutrient solution.

Prevention

Verify that that there is sufficient iron in your hydroponic nutrient solution recipe and that the nutrient solution was mixed correctly and all fertilizer injectors are operating correctly. As noted above, iron is typically supplied in nutrient solutions at 1-3 ppm. Most hydroponic nutrient solutions use a chelated form of iron which keeps the iron stable (reduces oxidation/precipitation) at higher pH. The three most commonly used chelating agents are EDTA, DTPA, and EDDHA. Chelators vary in their effective pH range. For EDTA at pH > 6.5 about half the iron is available and by pH 7 very little is available. For DTPA iron becomes increasingly unavailable above pH 7.5. EDDHA is stable to pH 11, however this is the most expensive chelating agent.

The primary method for preventing iron deficiency in hydroponics is maintaining proper pH of your nutrient solution. Suggested pH varies by crop, for hydroponic leafy greens and basil we recommend a pH of 5.5 to 6.0. In hydroponics pH can change much more quickly than in container production, often 1 to 2 units a day! Therefore, hydroponic growers should test and adjust pH a minimum of once daily. Always check your pH meter and recalibrate with standard solutions before taking measurements. Automated systems can be used whereby a pH meter connected to a computer controls the addition of dilute acids/bases to maintain a constant pH. If an automated system is used, it should still be checked manually at least daily. Again remember to check the pH sensor and recalibrate it as the sensor can drift over time.

Figure 4. Interveinal chlorosis of hydroponic arugula, 2 weeks after iron was discontinued from the nutrient solution.

Figure 5. Advanced iron deficiency of hydroponic arugula (4 weeks). Leaves also exhibit several small necrotic spots between veins.