Figure 257. Stunting, distortion, and crinkling of young leaves associated with boron deficiency. (J. Portner)

Figure 258. Misshapen shoot tip from boron deficiency. (J. Portner)

Figure 259: Misshapen, "fluffy-tipped" leaf due to boron deficiency. (T. McGee)

Nutrient Management and Imbalances

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Hop plants produce abundant biomass in the form of bines, leaves, and cones. High-yielding plants such as hop require adequate nutrition. Many of the various nutrients required by hop may be deficient or in excess of the crop's needs. It can be difficult to pinpoint the cause of abnormal plant symptoms, especially if multiple production factors lead to the same symptom. General symptoms associated with nutrient imbalances are described in this section, as well as known nutrient interactions with diseases and arthropod pests.

Fertilization recommendations are beyond the scope of this pest management guide and are not provided. Recommendations vary widely in published literature, differing among production regions, varieties, irrigation methods, soil types, and production goals. Readers should seek input from local experts for guidance appropriate to their region and situation.

Boron

Boron deficiency can result in delayed emergence of shoots; stunting, distortion, and crinkling of young leaves (Fig. 257); and yellowing and death of shoot tips (Fig. 258). Leaves of affected plants may be small and brittle, and may develop a fluffy-tipped appearance due to impaired development of lobes (Fig. 259). Deficiencies are most common in acid and/or sandy textured soils. Boron deficiency has been suggested as a contributing factor in red crown rot.

Calcium

Symptoms of calcium deficiency develop first in young tissues and at growing points. Symptoms can be similar to boron deficiency and may include yellowing of growing points, reduced development of leaves, and yellowing and death of leaf margins. Excessive calcium can interfere with uptake of other nutrients and induce deficiencies in other positively charged ions (e.g., ammonium, magnesium, potassium).

Iron

Iron deficiency is first observed on young leaves as yellowing between veins, while veins remain green (Fig. 260, right-hand image, and Fig. 261). Iron deficiency is most common in alkaline soils, although it can be induced in highly acidic soils (approximately pH 5.7 or less) because of enhanced solubility and uptake of manganese.

Iron chlorosis (yellowing) is common when hop plants are forced to grow through the winter in a greenhouse. In these conditions, high nitrogen fertilization and rapid plant growth rates appear to exacerbate iron chlorosis.

Chlorosis of newly formed leaves from temporary iron and zinc deficiency is sometimes observed in spring—when soils are cold and wet— just after plants are fertilized with nitrogen and phosphorous (Fig. 260). This effect is more pronounced in young plantings than mature yards.

Figure 260. Second-year Cascade plants grown side-by-side in a hop yard in Oregon and photographed in mid-May. The plant at right was fertilized in early May with an ammonium nitrate solution and shows typical yellowing between veins associated with iron deficiency, whereas the asymptomatic plant at left was not fertilized. (D.H. Gent)

Magnesium

Symptoms appear first on older leaves as yellowing between leaf veins, and in severe cases can be followed by death of these areas and defoliation (Fig. 262). Magnesium deficiencies are most common in acid soils or where excessive potassium was applied.

Manganese

Manganese becomes limited in high pH (alkaline) soils and can be present at toxic levels under low pH (acidic) conditions. Symptoms of manganese deficiency are yellowing of young leaves and white speckling. Manganese accumulation in plant tissues increases at soil pH below 5.7, which interferes with iron uptake and can induce an iron deficiency.

Root feeding by hop cyst nematode is reported to reduce manganese uptake, as well as uptake of other nutrients.

Molybdenum

Molybdenum deficiencies appear first in older leaves as yellowing and white speckling. Deficiencies have been reported on hop grown in acidic soils (pH 5.7 or less). In some plants, molybdenum deficiency can be misdiagnosed as a nitrogen deficiency since affected plants can have a general yellowing.

Nitrogen

Symptoms of nitrogen deficiency include poor growth, stunting, and a general yellowing of plants that is most pronounced on older leaves (Fig. 263). Cones of nitrogen-deficient plants are smaller than cones on plants receiving adequate nitrogen. Excessive nitrogen fertilization can increase incidence of several diseases and arthropod pests, including powdery mildew, Verticillium wilt, spider mites, and hop aphids. Efforts should be taken to balance crop demands with nitrogen inputs and to avoid over-application of nitrogen, particularly at times in the season when a pest of concern is present. For instance, large doses of nitrogen applied later in the season (e.g., late June to early July) may induce spider mite outbreaks. Conversely, some evidence suggests that unduly low rates of nitrogen fertilization also may increase spider mites.

The form of nitrogen may affect certain diseases. Fusarium canker appears to be favored by use of ammonium-based nitrogen fertilizers, whereas nitrate-based fertilizers favor Verticillium wilt. These interactions involve relationships between the fertilizer components, the soil pH, and the availability or uptake of other nutrients (i.e., manganese and zinc).

Solutions of ammonium nitrate are used occasionally to defoliate basal leaves on hop. Some small annual weeds also are sensitive to ammonium nitrate sprays.

Figure 261. Yellowing of the youngest leaves resulting from iron deficiency. Notice that symptoms are less pronounced on older leaves. (J. Portner)

Figure 262. Yellowing and death of tissue between leaf veins caused by magnesium deficiency. (C.B. Skotland)

Figure 263. Weak growth and yellowing of lower leaves associated with nitrogen deficiency. (J. Portner)

Soil and Tissue Testing

Growers are encouraged to monitor soil and plant nutrients through soil and petiole/leaf testing to ensure sufficient, yet not excessive, nutrient uptake.

Annual soil testing can provide a snapshot of current soil conditions and guide fertilizer needs to optimize yield and potentially reduce incidence of arthropod pests and disease. At a minimum, testing should include pH (see sidebar on p. 100) and macronutrients such as potassium, phosphorous, calcium, and magnesium. Sulfur can also be assayed, although predicting plants' needs from soil tests is difficult. Determining levels of the micronutrients boron, iron, manganese, molybdenum, and zinc is also recommended, as deficiencies have been noted in other crops. Soil pH may have to be adjusted over time to ensure proper uptake of these nutrients.

Petiole and tissue testing are also encouraged and can provide an indication of nutrient uptake. Growers should work with local laboratories to determine appropriate protocol for taking and submitting petiole samples. Results should be collected annually and compared with plant growth and yield to best inform management decisions.

pH

Soil pH influences several biological and chemical processes. Excessively low or high pH may induce nutrient deficiencies and/or toxicities, and may interact with disease development.

Surface soil pH acceptable for hop production is reported to **range from 5.7 to 7.5**, although the influence of surface pH on yield is less clear.

Acid soil pH tends to favor Fusarium pathogens, but may suppress Verticillium wilt.

Alkaline soil pH tends to suppress Fusarium diseases (due in part to immobilization of zinc), whereas it favors Verticillium wilt.

The **form of nitrogen applied** can influence pH and, ultimately, susceptibility to certain diseases. Ammonium (NH_4) sources of nitrogen tend to be acidifying, whereas some nitrate (NO_3) fertilizers increase soil pH, therefore selection of a particular form of nitrogen may moderate disease levels in some instances.

Figure 264. Weak growth and reduced side arm development associated with zinc deficiency. (C.B. Skotland)

Phosphorus

Symptoms of deficiency first appear on lower leaves as downcurved, dark-green leaves with a dull appearance. Bines are thin and weak. Affected cones may have a brown discoloration. Studies in England indicate that although symptoms may not be apparent, yield can decrease substantially when hop plants are deficient in phosphorous.

In addition to having deleterious effects on water quality, excessive phosphorous fertilization may induce zinc deficiencies, particularly in alkaline soils or soils otherwise marginally deficient in zinc. Phosphorous acid (phosphite) compounds often are applied as part of foliar fertilizers and can suppress downy mildew, black root rot, and, to a limited extent, powdery mildew. However, phosphorous acid itself has no plant nutritive value.

Potassium

Potassium deficiency results in weak bine growth and reduced burr formation. Symptoms develop first on older leaves, appearing as a bronzing between veins. These bronze areas become an ashy gray, and leaves may be shed prematurely. Excessive potassium fertilization also may induce magnesium deficiencies, and potassium deficiencies may reduce nitrogen use efficiency.

Sulfur

Deficient plants have stunted growth, spindly stems, and yellowing of younger leaves. In general, soils with high leaching potential may be deficient in sulfur. Sulfur is commonly deficient in the acidic, coarse-textured soils of western Oregon.

Zinc

Hop plants are very sensitive to zinc deficiency. Plants deficient in zinc have weak growth, short lateral branches, and poor cone production (Fig. 264). Leaves are small, misshapen, yellow, curl upward, and can become brittle (Fig. 265). In severe cases, affected plants may die. Zinc deficiencies occur frequently when soil pH is greater than 7.5, which is common in central Washington. Zinc applications can cause remission of symptoms associated with *Apple mosaic virus.*

Figure 265. Cupped, brittle leaves caused by zinc deficiency. (J. Portner)