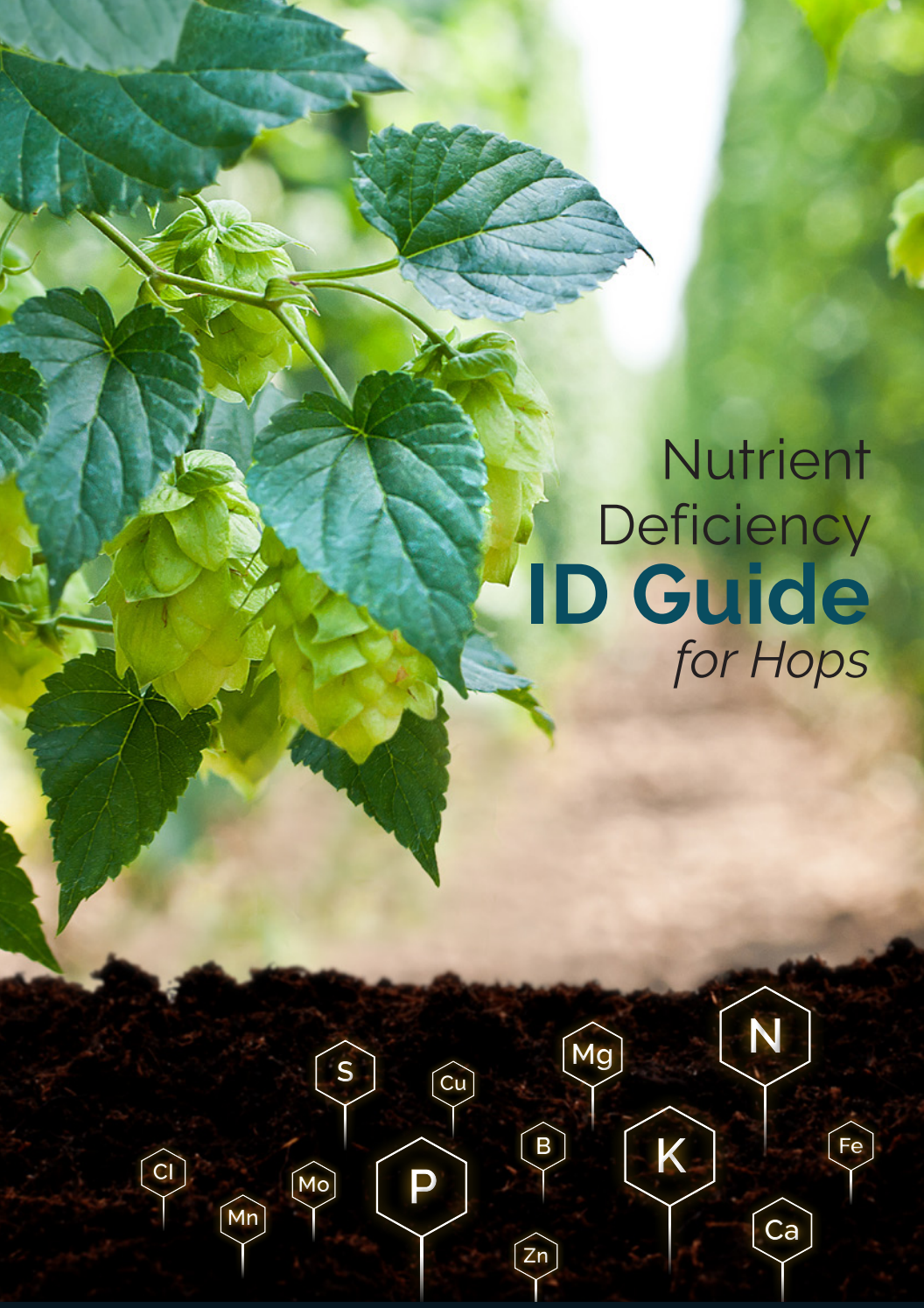
Nutrient Deficiency ID Guide *for Hops*



Ontario

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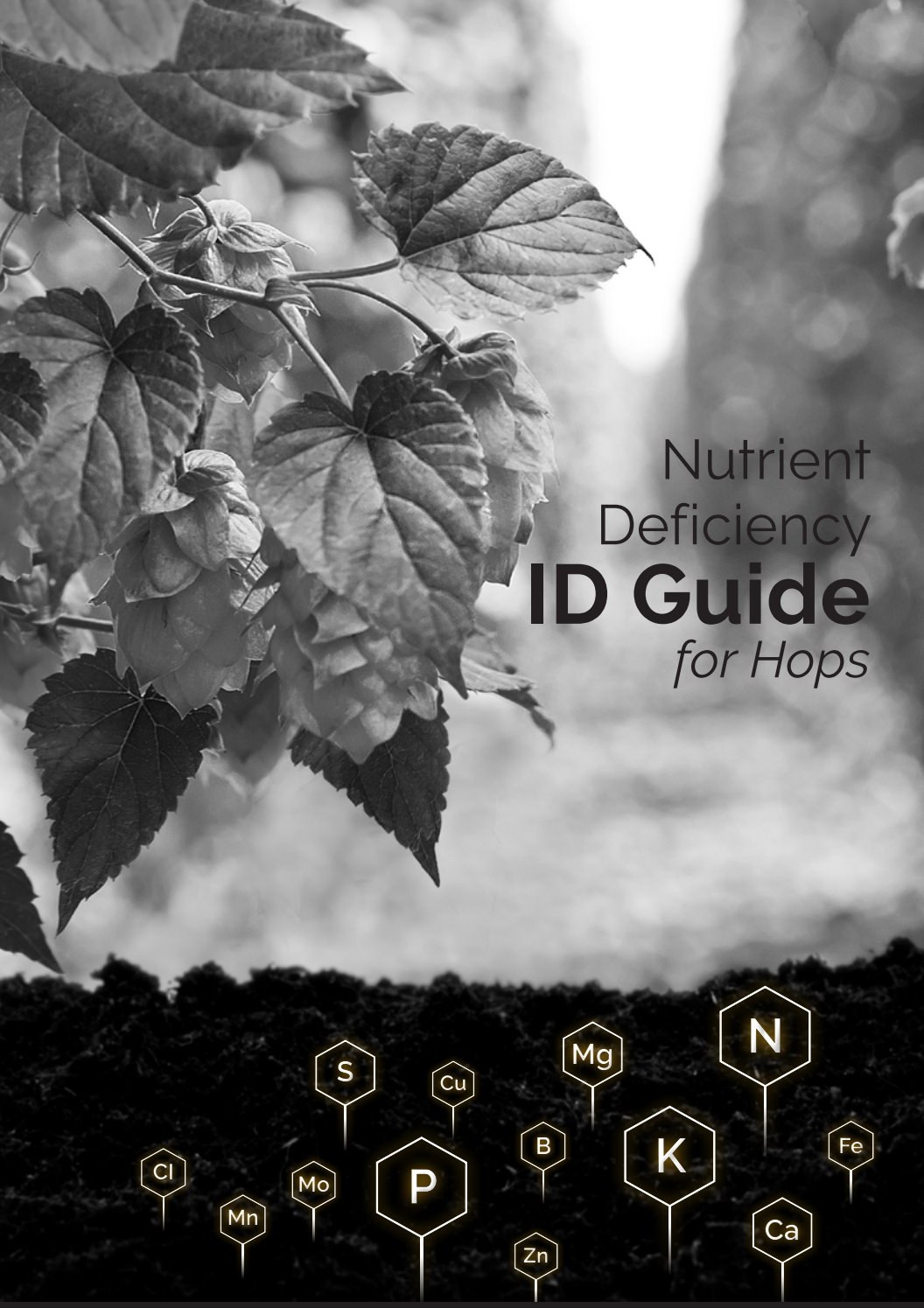

Ontario

Nutrient Deficiency ID Guide for Hops

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*If you require technical or business information, contact the Agricultural Information Contact Centre at **1-877-424-1300** or **ag.info.omafra@ontario.ca***

Contents

Table 1. Form and mobility of nutrients and micronutrients in soil and plants.

Nutrients	Mobility in Soil	Plant available forms in soil	Mobility in plant
Primary Nutrients			
Nitrogen	medium	ammonium ion (NH_4^+)	high
Nitrogen	high	nitrate ion (NO_3^-)	high
Phosphorus	low	phosphate ion ($H_2PO_4^-$, HPO_4^{2-})	high
Potassium	low–medium	potassium ion (K^+)	high
Secondary Nutrients			
Calcium	low	calcium ion (Ca_2^+)	low
Magnesium	low	magnesium ion (Mg^{2+})	high
Sulphur	medium	sulphate ion (SO_4^{2-})	low–medium
Micronutrients			
Boron	high	boric acid ($B(OH)_3^0$, borate ion ($H_2BO_3^-$)	low–medium
Chlorine	high	chloride ion (Cl^-)	high
Copper	low	cupric ion (Cu_2^+)	low
Iron	low	ferrous ion (Fe^{2+}), ferric ion (Fe^{3+})	low
Manganese	low	manganous ion (Mn^{2+})	low
Molybdenum	low–medium	molybdate ion (MoO_4^{2-})	medium–high
Zinc	low	zinc ion (Zn^{2+}), zinc hydroxide $Zn(OH)_2^0$	low

Source: OMAFRA, Publication 611, *Soil Fertility Handbook*, Table 3-3.

Introduction

As hop (*Humulus lupulus* L.) production has re-emerged across Ontario and Northeastern North America, growers continue to request more detailed information on how foliar symptoms found in the crop relate to various nutrient deficiencies. Resources for visual identification of nutrient deficiency symptoms in hops are limited. Those currently available typically have old, poor-quality photos that do not cover the full nutrient spectrum, or the progressive development of deficiency symptoms seen in the field.

The ability to identify nutrient deficiencies quickly and accurately allows growers to improve nutrient use efficiency, crop health and overall yields of marketable product. This pictorial guide was developed for growers to better identify foliar symptoms caused by nutrient deficiencies in hop plants, however, it is advised to always confirm a visual diagnosis with laboratory analysis.

Female hop plants (cv. Cascade) were grown under standard greenhouse conditions. Plants were sourced from virus-tested mother plants. Supplemental lighting was provided to ensure plants did not convert to reproductive mode. Individual nutrient solutions, each deficient in one of the 13 macronutrients or micronutrients (Table 1), and one complete nutrient treatment based on Hoagland's solution corrected to pH 6.5, were applied to plants for the duration of the project. A pH of 6.5 was chosen because all nutrients are available at that pH (Figure 1). Photos were taken of deficiency symptoms at multiple stages for each nutrient and a companion illustration of the types of symptoms that occur with nutrient deficiencies is provided (Figure 2) along with photos of leaves grown with the complete nutrient treatment (Figure 3).

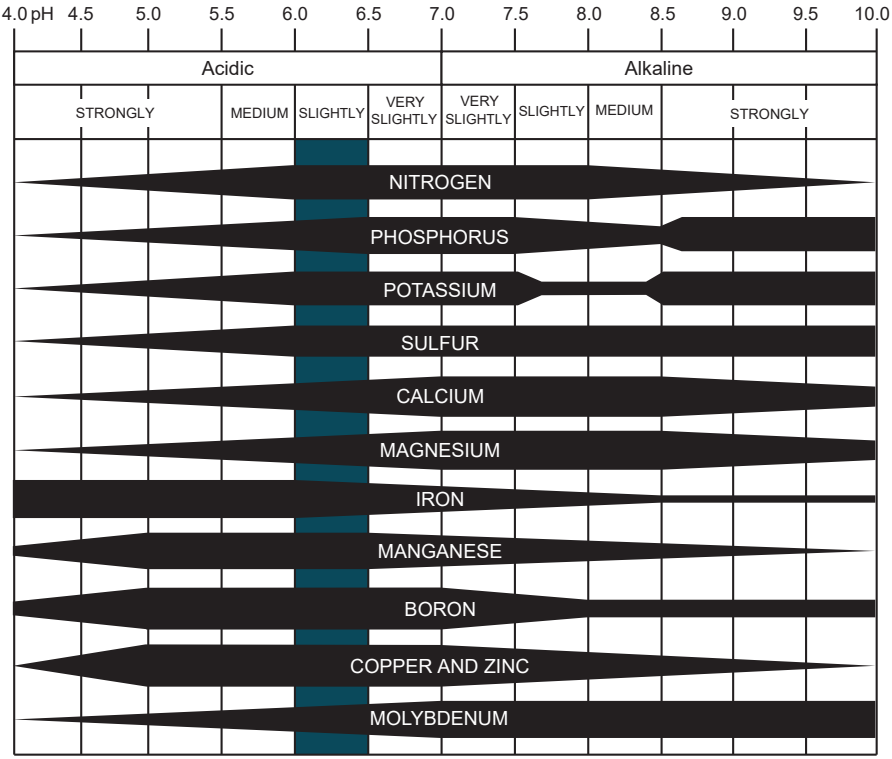

Figure 1. *Effect of pH on the root availability of the essential elements in soil. Blue denotes the ideal soil pH for the majority of plants (slightly acidic).*
Source: Wikimedia Commons[1]

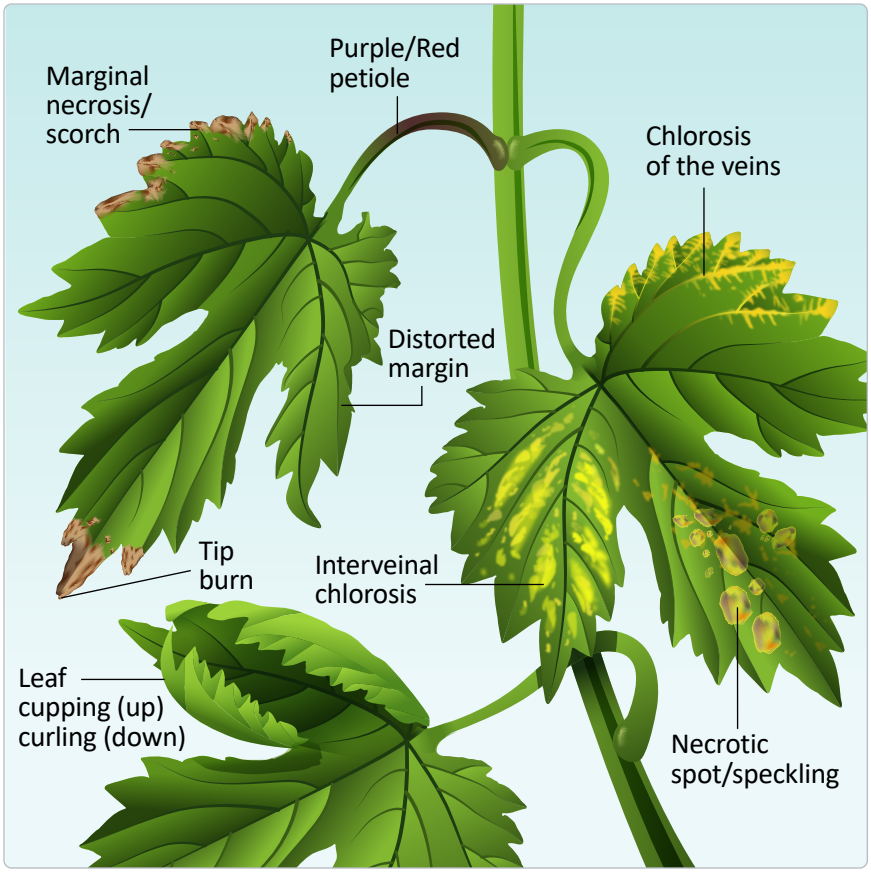

Figure 2. *Illustration of typical symptoms that occur in a leaf when a plant experiences nutrient deficiencies.*

Figure 3. *Healthy hop leaves from plants grown with complete nutrient solution to use as a reference comparison to the nutrient deficient photos contained within this guide.*

Nitrogen (N)

Primary Nutrient

Role

Nitrogen is involved in many plant processes and structures. Compared to other nutrients, it is required in large amounts. Nitrogen is a main component of amino acids, which form proteins within the plant. Enzyme proteins are important in several plant processes, particularly those which impact growth and yield. Protein is usually highest in the harvested part of the plant hence it often is an important item in the nutritional value of the crop. Nitrogen has an important role in the production of chlorophyll, which gives the green colour in plants. Chlorophyll is responsible for the conversion of sunlight to energy needed by the plant through the process of photosynthesis.

Mobility

Nitrogen is a mobile element in the plant.

Impact of pH

Availability decreases under highly acidic or alkaline conditions.

Deficiency Symptoms

Plants suffering nitrogen deficiency are usually a pale green to yellow, with symptoms first occurring in the older leaves which may show some red or purple tinting, particularly in the veins and petioles of broadleaf plants. Plants may show reduced vigour.

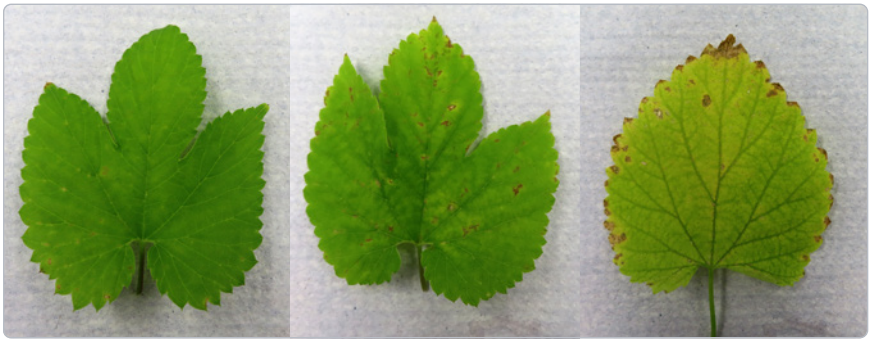

Figure 4. *Progression of leaf yellowing due to nitrogen deficiency in young to old leaves (left to right). Note the pale green colour and dull sheen on leaves. These deficiency stages are commonly seen in the field when nitrogen is lacking.*

Figure 5. *Progression of leaf yellowing and minor marginal necrosis in hops from healthy leaf (left) to very deficient leaf (right). Yellowing, as seen in the leaf on the far-right of the photo, is typically only found in extremely deficient plants.*

Phosphorus (P)

Primary Nutrient

Role

Like nitrogen, phosphorus is an important factor in many plant metabolic processes such as photosynthesis and respiration, energy storage and transfer (ATP), protein and carbohydrate metabolism, and cell division and enlargement. It is also integral to the structure of DNA and is an important component of cell membranes. The effect of the availability and supply of phosphorus on these plant processes and structures is reflected in specific aspects of crop growth. When phosphorus is limited, plants adjust by shifting more resources to root production and less to top growth.

Mobility

Phosphorus is a mobile element in the plant.

Impact of pH

Availability begins to decrease below pH 6.

Deficiency Symptoms

Purpling in plants is associated with phosphorus deficiency, but this symptom is unreliable. The production of anthocyanin, which creates the purple colour, is a standard stress response. Many other factors can induce purpling. Common phosphorus deficiency symptoms include slow-growing plants, older leaves exhibiting dark-green colour in early deficiency stages, delayed plant maturity and spindly, small leaflets. Older leaves typically progress from dark green to bronze tinting with interveinal and marginal necrosis (browning). There may also be a decrease in the number and size of buds or flowers.

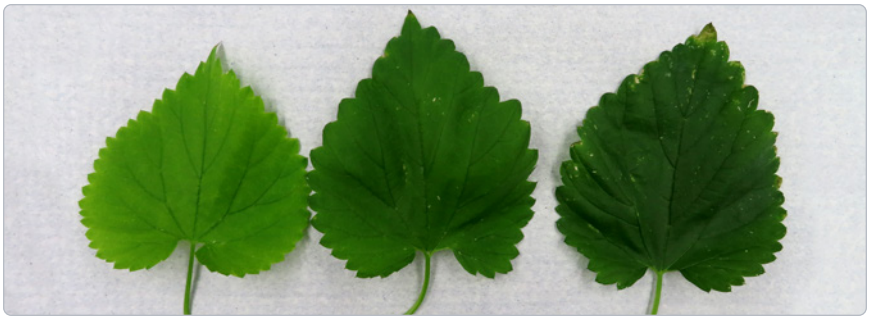

Figure 6. *Progression of leaf darkening in early stages of phosphorus deficiency (left to right).*

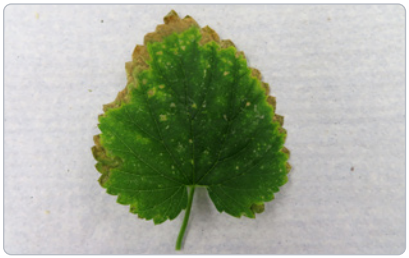

Figure 7. *Minor marginal necrosis (marginal scorch) due to phosphorus deficiency.*

Figure 8. *Severe marginal scorch due to prolonged phosphorus deficiency.*

Figure 9. *Progression of interveinal chlorosis to marginal necrosis due to phosphorus deficiency (left to right).*

Figure 10. *Interveinal necrosis sometimes exhibiting a grey or bronze tinting after prolonged phosphorus deficiency.*

Potassium (K)

Primary Nutrient

Role

Potassium promotes formation of structural components including lignin and cellulose, which play a major role in stalk strength and lodging resistance. It influences the uptake of carbon dioxide, photosynthesis and the regulation of stomatal opening in the leaves, water uptake by roots, starch and sugar content and cell integrity, and aids in disease and insect resistance.

Mobility

Potassium is a mobile element in the plant.

Impact of pH

Availability decreases below pH 6 and between pH 7.6 to 8.4.

Deficiency Symptoms

Since potassium is mobile within the plant, deficiency symptoms usually appear first on older leaves, often as a chlorosis (yellowing) or necrosis of the leaf margins known as 'marginal scorch'. Older leaves often curl downwards. Potassium deficiency may also cause shorter internodes.

Figure 11. *Progression of chlorosis and marginal necrosis due to potassium deficiency (top left to bottom right).*

Figure 12. *Severe chlorosis and necrosis due to prolonged potassium deficiency.*

Calcium (Ca)

Secondary Nutrient

Role
Calcium is important in the stabilization of the cell wall and is involved in the metabolism and formation of the cell nucleus.

Mobility
Calcium is an immobile element in the plant. Uptake is depressed by ammonium-based nitrogen, excessive potassium, magnesium, manganese and aluminum.

Impact of pH
Availability declines below pH 6.5.

Deficiency Symptoms

Plants demonstrate slow growth and reduced size eventually resulting in no further elongation of the growing points and finally death of the growing points. Leaves typically turn pale green during early onset of calcium deficiency. Leaves, particularly new growth, progress with patches of yellow to brown interveinal spotting and necrosis. Leaf cupping or curling can also occur.

Figure 13. *Young leaves progressing from pale green to light yellow with some minor necrotic spotting as a result of calcium deficiency (left to right).*

Figure 14. *Progression of necrotic spotting on older leaves as a result of calcium deficiency (top left to bottom right).*

Figure 15. *Leaf cupping and extensive necrotic spots will develop with prolonged calcium deficiency.*

Magnesium (Mg)

Secondary Nutrient

Role

Magnesium is required for the synthesis of chlorophyll for photosynthesis. It also aids phosphate movement and is a component of enzymes involved in plant respiration and DNA/RNA synthesis.

Mobility

Magnesium readily moves through the plant.

Impact of pH

Optimally available between pH 6.5 and 8.5.

Deficiency Symptoms

Magnesium is a mobile element, so older leaves are the first to display signs of deficiency. These typically include interveinal chlorosis or reddening followed by marginal leaf necrosis, leaf cupping or curling and development of necrotic patches. Magnesium deficiency symptoms may appear similar to potassium and manganese deficiency symptoms however, manganese deficiency symptoms usually occur first in younger leaves compared to magnesium and phosphorus deficiency symptoms first occurring in older leaves.

Figure 16. *Leaf curling is a common feature of magnesium deficiency.*

Figure 17. *Early development of necrotic patches due to magnesium deficiency.*

Figure 18. *Necrosis on the margins (marginal scorch) is a common symptom of magnesium deficiency.*

Figure 19. *Severe interveinal chlorosis due to prolonged magnesium deficiency. Some leaf cupping or curling may also be evident at this stage.*

Figure 20. *Progression from healthy to severely magnesium deficient leaves (left to right).*

Sulphur (S)

Secondary Nutrient

Role

Sulphur is a constituent of two of the 21 amino acids that form proteins. It also helps develop enzymes and vitamins, is involved in nitrogen fixation in legumes, aids in seed production and is needed for chlorophyll formation.

Mobility

Sulphur is an immobile element in the plant.

Impact of pH

Availability decreases below pH 6.0.

Deficiency Symptoms

Plants suffering sulphur deficiency are usually a pale green and may show some red or purple tinting similar to nitrogen deficiency symptoms. The younger leaves may be more chlorotic than the older leaves due to the sulphur being immobile in the plant. Stems can become woody in appearance with shortened internodes.

Figure 21. *Progression of necrosis in younger leaves due to sulphur deficiency (left to right).*

Figure 22. *Progression of interveinal chlorosis and marginal necrosis in older leaves due to sulphur deficiency (left to right).*

Figure 23. *Pale green leaves (left) and marginal necrosis (right) are common symptoms from sulphur deficiency.*

Figure 24. *Severe marginal necrosis and leaf cupping after prolonged sulphur deficiency.*

Figure 25. *Interveinal necrotic patches after prolonged sulphur deficiency.*

Boron (B)

Micronutrient

Role

Boron plays an important role in the structural integrity of cell walls, fruit set, seed development and carbohydrate and protein metabolism.

Mobility

Boron is an immobile element in the plant.

Impact of pH

Availability declines above pH 7.5.

Deficiency Symptoms

Symptoms first appear on younger tissues, commonly as distorted (curled) leaves that become thicker with age. Interveinal chlorosis followed by necrosis is evident. In general, vegetative growth will be poor. Growing points typically die back, and buds or flowers may be deformed or die.

Figure 26. *Early symptoms of boron deficiency include downward curling on leaf margins.*

Figure 27. *Death of growing points is a common symptom of boron deficiency in hops.*

Figure 28. *Severe distortion of younger leaves due to boron deficiency.*

Figure 29. *Progression of interveinal chlorosis on older leaves leading to necrosis as a result of prolonged boron deficiency (left to right).*

Chlorine (Cl^-)

Micronutrient

Role

Chlorine in plants plays an important role in stomatal regulation and water flow. Chlorine is also involved in photosynthesis.

Mobility

Chlorine is readily soluble and highly mobile within the plant.

Impact of pH

Mobility not affected by pH.

Deficiency Symptoms

Plants will demonstrate reduced growth. Wilting or limpness of growing points and young leaves is typical of early chlorine deficiency symptoms followed by the development of chlorotic and necrotic spots. Younger leaves may also demonstrate leaf cupping. Bronzing of the leaves occurs after prolonged deficiency.

Figure 30. *Leaf cupping and minor chlorotic and necrotic spots on a young leaf due to chlorine deficiency.*

Figure 31. *Bronzing on the leaf surface is a common symptom of chlorine deficiency.*

Figure 32. *Progression of chlorotic to necrotic spots and margins on older leaves due to chlorine deficiency (top left to bottom right).*

Copper (Cu)

Micronutrient

Role

Copper plays a role in chlorophyll production and proper enzyme function.

Mobility

Copper is an immobile element in the plant.

Impact of pH

Availability declines above pH 8.0.

Deficiency Symptoms

Leaves, particularly new growth, will develop a dark blueish-green colour and show signs of wilting. With time, leaves become chlorotic and may begin to curl.

Figure 33. *Blueish-green leaves that are beginning to curl are symptoms of early stages of copper deficiency.*

Figure 34. *Progression of chlorosis to necrosis in young leaves due to copper deficiency (left to right).*

Figure 35. *Progression of chlorosis in older leaves due to copper deficiency (left to right).*

Figure 36. *Progression of older blueish-green leaves with chlorotic and necrotic spots due to copper deficiency (top left to bottom right). Note curling leaf margins.*

Figure 37. *Leaf bronzing may also occur on hops with copper deficiency.*

Iron (Fe)

Micronutrient

Role

Iron has a number of functions within plants. It is a catalyst in the formation of chlorophyll and is required for plant respiration and functions in the formation of some proteins.

Mobility

Iron is an immobile element in the plant.

Impact of pH

Availability declines above pH 7.5.

Deficiency Symptoms

The first signs of iron deficiency appear on the younger leaves which show interveinal chlorosis or striping along the entire length of the leaf. Interveinal chlorosis progressively develops from light green to light yellow or white, eventually showing the appearance of brown patches of dead tissue. Leaves stay alive during iron deficiency and only die after prolonged iron deprivation. In severe cases, plant growth will be stunted.

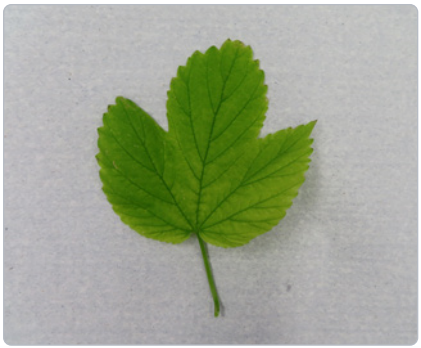

Figure 38. *A lack of iron results in young leaves showing interveinal chlorosis starting from the base of the leaf.*

Figure 39. *Progression from light green to yellow of leaf tissue due to iron deficiency (left to right).*

Figure 40. *Prolonged iron deficiency results in severe necrosis leading to leaf death.*

Manganese (Mn)

Micronutrient

Role

Many enzyme systems require manganese for proper function, including those involved in the distribution of plant growth regulators within the plant. It is involved in photosynthesis and chlorophyll production.

Mobility

Manganese is an immobile element in the plant.

Impact of pH

Availability declines above pH 7.5.

Deficiency Symptoms

The first signs of deficiency appear on the younger leaves. Leaf margins and veins may look darker green than the rest of the leaf. Interveinal yellowing progressively develops into the appearance of necrotic speckling or patches of dead tissue. Manganese deficiency symptoms may appear similar to potassium and magnesium deficiency symptoms however, manganese deficiency symptoms usually occur first in younger leaves compared to magnesium and phosphorus deficiency symptoms first occurring in older leaves.

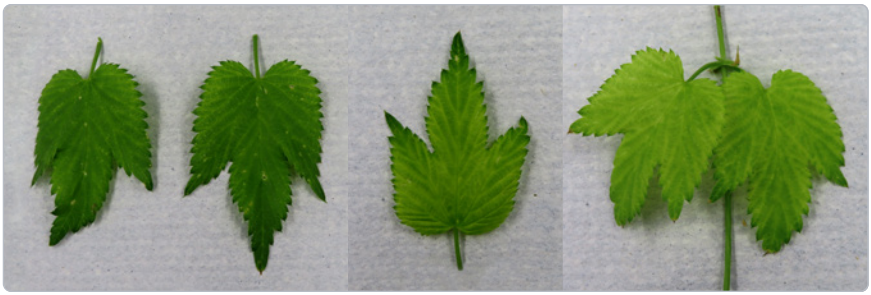

Figure 41. *Young leaves typically exhibit dark green leaf margins due to manganese deficiency.*

Figure 42. *Dark green veins, minor interveinal yellowing, and necrotic speckling develops as the leaf ages due to manganese deficiency.*

Figure 43. *Progression of necrotic speckling and patches due to manganese deficiency (top left to bottom right).*

Molybdenum (Mo)

Micronutrient

Role

Molybdenum plays an important role in nitrogen metabolism within the plant as it is an essential component of nitrate reductase, the enzyme that converts nitrate (NH_3-) to ammonium (NH_4+). It also plays a role in pollen viability and seed production.

Mobility

Molybdenum is a mobile element in the plant.

Impact of pH

Availability increases above pH 7.0.

Deficiency Symptoms

A lack of molybdenum impacts nitrogen metabolism, so molybdenum deficiency symptoms may be similar to nitrogen deficiency symptoms including yellowing, plant stunting, scorching of the leaf margins and cupping or rolling of leaves. Deficiency symptoms first occur in older leaves and then progress to the younger, expanding leaves. Both younger and older leaves may develop chlorotic spots that eventually perforate but leave the rest of the leaf tissue green for a prolonged time period.

Figure 44. *Minor yellowing of leaves in early stages of molybdenum deficiency.*

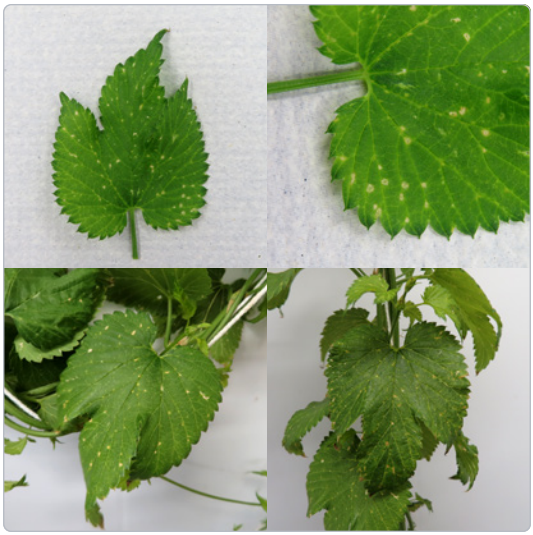

Figure 45. *Progressive development of necrotic spots that eventually perforate while leaving the rest of the leaf tissue green (top left to bottom right).*

Figure 46. *Progression of marginal scorch, interveinal chlorosis, and necrotic spots due to molybdenum deficiency (left to right).*

Figure 47. *Molybdenum deficiency can deform younger leaves.*

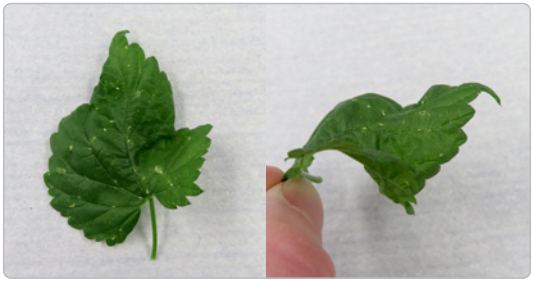

Figure 48. *Leaf curling is a common symptom of molybdenum deficiency. The same leaf is shown here from the top and side profiles.*

Zinc (Zn)

Micronutrient

Role

Zinc is important in early plant growth and in grain and seed formation. It plays a role in chlorophyll and carbohydrate production.

Mobility

Zinc is an immobile element in the plant.

Impact of pH

Availability declines above pH 8.0.

Deficiency Symptoms

Interveinal chlorosis is evident in the youngest tissues which may appear as pale to white bands between the leaf margin and mid-vein in the lower part of the leaf. In severe cases of zinc deficiency, newly emerged leaves can be completely white. In addition, the developing leaves may be thin with distorted margins.

Figure 49. *Leaf cupping followed by marginal necrosis and necrotic spots on young leaves with zinc deficiency (left to right).*

Figure 50. *Interveinal chlorosis progressing to necrosis on older leaves due to zinc deficiency (left to right). The symptoms commonly begin at the leaf tip of the midrib and progress outwards.*

Figure 51. *Early bronzing of leaf surface due to zinc deficiency.*

Figure 52. *Later stages of bronzing and interveinal/marginal necrosis due to zinc deficiency.*

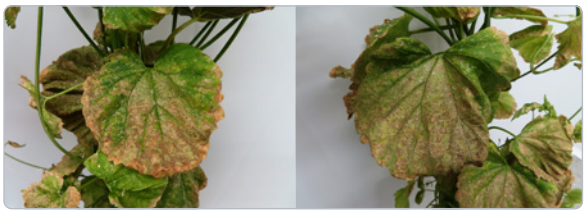

Figure 53. *Severe necrosis after prolonged zinc deficiency.*

Glossary

Bronzing: A reddish-brown discoloration or flecking of plant tissues, especially leaves, in response to damage from a pest (e.g. mite feeding) or environmental stress (e.g. sunscald, excess ozone, nutrient deficiency). Leaves may also appear curled and pale green in colour.

Chlorosis: Bleaching (yellowing) of plant tissues due to a loss of chlorophyll.

Internode: The part of a stem or rhizome between any two nodes.

Interveinal: Area located between the veins that occur in leaves.

Intraveinal: Occurring within the leaf veins.

Margin (leaf): Area along the edge of the leaf.

Micronutrient: Micronutrients are as important as the primary and secondary nutrients but are needed in much smaller quantities by the plant and are often less prevalent in the soil.

Mobile Nutrient: Any nutrient that can move freely within the plant. Mobile nutrients move to the areas of new growth, which can result in older tissues displaying deficiency symptoms.

Necrosis: Premature tissue death resulting from disease, injury or physiological stress (e.g., nutrient deficiency, ozone etc.). Necrosis can occur within the body of the leaf, along the leaf margins, or in both locations.

Necrotic Speckling/Stippling: Numerous small, white or bronzed puncture marks on the leaf.

Petiole: The stalk of a leaf, attaching the blade to the stem.

Primary Nutrient: A primary nutrient, or macronutrient, is required by plants in large quantities for basic plant growth and development. The six nutrients that fall into this category are carbon, hydrogen, oxygen, nitrogen, phosphorus and potassium. Plants acquire carbon, hydrogen and oxygen from the air and water. The remaining macronutrients must be obtained from the soil. Fertilizer, manure, nitrogen fixation and mineral weathering replenish soil nutrients. Primary nutrients most frequently limit plant growth.

Secondary Nutrient: Calcium, magnesium and sulphur are required in moderate amounts. They are usually classified as secondary nutrients because they are less likely to limit crop growth. These nutrients are usually present in the soil in adequate amounts, although fertilization may be required for certain crops.

Scorch (leaf): Sudden leaf death or browning, either interveinally or at the margin that occurs when plants have difficulty taking up water or have sudden exposure to full sunlight following a wet, cloudy period.

Stunting: Reduced plant growth due to a pest or a lack of water, nutrients or other necessity for plant development.

Citations

1 Wikimedia Commons, *File:Soil pH effect on nutrient availability.svg*, https://commons.wikimedia.org/w/index.php?title=File:Soil_pH_effect_on_nutrient_availability.svg&oldid=634347869#filelinks. Accessed March 14, 2023, Creative Commons Attribution 4.0 International license.

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