

PART 1: Nutrients Needed for Proper Crop Development

Section A: Overview

Most people know that proper plant growth requires **NUTRIENTS** that provide adequate levels of Nitrogen, Phosphorus and Potassium. In addition to these primary macronutrients, secondary macronutrients (such as calcium, sulfur and magnesium) and trace elements (boron, chlorine, manganese, iron, zinc, copper, molybdenum, and nickel) must be present within the growing medium in order for the plants to develop properly. These nutrients are absorbed through the growing medium by the root system of the plant through a process known as **CATION-EXCHANGE** in which root hairs pump hydrogen ions (H⁺) into the soil, which displace cations attached to soil particles, which makes the nutrients that are positively charged available for uptake by the root hairs.

The Cation Exchange is the driving force behind most of the mechanism used for nutrient uptake. In most cases the soil particles have a negative charge and attract the cations that are available in the soil. As with all chemical reactions, some have a stronger bond than others. In decreasing holding strength, the order with which cations are held by the soil particle is as follows: aluminum, hydrogen, calcium, potassium and nitrate, and sodium.¹ These chemical reactions are part of the process that enables the plant to acquire the needed elements for plant growth.

Measurements of nutrients within the plant take the form of a percentage of nutrients (Nitrogen 5.0%) or the concentration of the nutrient in parts per million (25 ppm Zinc). These measurements are simply an indication of the amount of nutrients that exist in the plant. It is up to the farmer and the agronomist to understand the deficiency and what nutrients should be adjusted in each of the fields in an effort to enhance the symbiotic relationships that exist between the plant nodules and the natural soil **BACTERIA** and **MYCORRHIZAL FUNGI** all in an effort to enhance the cation exchange.

For traditional growth of vegetation, most of the planet has sufficient macronutrients in the soil. But with enhanced technology and less expensive analysis, farmers are looking to amend their soil more often and more responsibly. These actions are a result of better knowledge of plant and pests, better awareness of soil conditions, better analytical lab analysis of soil and plant tissues, as well as more effective visual inspections of the field (known as scouting).

NUTRIENTS are the nutritional needs that a plant needs to survive and grow. They enable cell development, energy conversion and metabolism.

CATION-EXCHANGE is the number of exchangeable *cations* per dry weight that a soil is capable of holding, at a given pH value, and available for *exchange* with the soil water solution.

BACTERIA carry out biological nitrogen fixation, in which atmospheric nitrogen (N₂) is converted into ammonium (NH₄)

MYCORRHIZAL FUNGI on the plant roots help to create a larger effective root surface area.

Scouting: Farmers spend time walking through the fields, and sometimes using remote control helicopters, to monitor plant growth. This is known as scouting. Scouting allows the farmer to evaluate the needs of the plants and identify any concerns. University Extension programs from land grant institutions produce reliable references that serve as a guide for farmers. The farmers also look to agronomists from either the seed company or the co-op that they are part of to help create a management prescription for each individual field. The farmer then has to weigh the options between the area affected and the result of the symptom on the yield that the crop will produce. Ultimately, it becomes a cost-benefit analysis.

¹ Soil Management. Retrieved 03 April 2015, from http://www.ctahr.hawaii.edu/mauisoil/c_relationship.aspx
Managing Nutrient Needs in Agriculture

Reading Questions

1. Explain the process of nutrient uptake using the cation exchange.

2. Support the reasoning that a farmer needs to enhance the cation exchange.

3. Why would farmers want to take the time to “scout” their fields?

Section B: A Closer Look at Nutrient Movement

An understanding of the pathways in which nutrient ions move throughout the plant system is important so that the right application of nutrients has the desired outcome. The goal for the plant is to move nutrients where they are needed and produce more **MERISTEM** cells, allowing for the plant to grow. Conceptualization of the movement of nutrients is important so one can understand the implications and applications of the biogeochemical processes that reside in the growth environment, which in turn, will help to clarify the nutrient movement within the system.

Recall that leaves absorb solar energy and convert it to chemical energy in the process known as **PHOTOSYNTHESIS**. (This is what distinguishes them as an autotroph.) Nutrients move to the location in the plant where they are needed most and this is done through the **PHLOEM** and the **XYLEM**.

The root system can be simple (monocot) or complex (dicot) but the attributes of the root are the same. Each branch of the root has smaller “hair-like” structures that are the site of uptake. Uptake is based on the density of the root system – the more roots, the more potential to create pathways. The site where the hair contacts the soil is a micro ecosystem and it allows for the nutrients to be drawn into the plant through diffusion.

The Root System

To visualize the pathway in which the root system allows for nutrients to enter into the plant, consider a shopping trip to the nearest mall. As the potential buyer, you are the nutrient and any point of sale would be considered the plants uptake of the nutrient.

As you walk into the mall you enter through one of the large anchor stores. As you walk through you see an item that you absolutely must have. You stop and check out the price and make a purchase. This is what happens when **root interception** occurs. The nutrient is in the soil and it just comes into contact with the root system. Mycorrhizal fungi on the root tips are like the mannequins that you walk past, which increase your odds of looking.

As you continue your mall experience, the group that you are with wants to enter another store. You decide to enter and once again you decide to make a purchase. The group represents water as it carries nutrients. This represents **mass flow**, when nutrients are transported to the root system by the movement of water.

Now, consider a trip to the food court where there are many people (remember people represent nutrients). You are hungry and your decision on what to buy leads you to the line that has the least amount of people. This is **diffusion**, where you move from an area of high concentration to low concentration.

PHOTOSYNTHESIS is the process of converting light energy into chemical energy by using water and carbon dioxide.

PHLOEM carries soluble organic material, that is made in photosynthesis, to all parts of the plant.

XYLEM transports inorganic molecules using water to carry nutrients throughout the structure of the plant.

MERISTEM cells enable the plant to grow. *Shoot apical meristem* allow leaves and flowers to grow, where as, the *root apical meristem* promotes growth in root system.

Absorption into the plant cell

The barriers, known as membranes (e.g. plasma membrane and tonoplast) are contained within the cell of a plant. Think of the barriers as security at a concert. Security's job is to manage the people who come into the concert hall with the intent of keeping anything bad from coming into the concert. It is the same for the membranes within the cell of the plant. But instead of regulating people, the barriers regulate the absorption of nutrients into the cell. These membranes are semi permeable to water, but they are permeable to oxygen, carbon dioxide, and other compounds such as amino acids and sugars. In addition, nutrient ions are able to move across these barriers either actively or passively.²

pH Scale

Understanding the pH of the soil is imperative when trying to manage the movement of nutrients in soil. But the pH scale is often misunderstood.

When asked, most people will respond that the pH scale is a measure of the acidity and alkalinity of a substance on a logarithmic scale. Where this is true, the scale really is the classification that distinguishes the measurement of the amount of hydrogen ions in a substance. The Danish biochemist Søren Sørensen proposed the term pH to refer to the "potential of hydrogen ion."³ Recall that the hydrogen ion is H^+ . Knowing that pH refers to the amount of hydrogen ions (H^+) then one can start to see how ions in the soil start to move.

Reading Questions

1. What is the significance of meristem cells?

2. Identify and explain the three ways in which the root system allows nutrients to enter the plant.

3. Why are membranes important to the plant?

4. Explain why it is important to understand the pH scale when addressing nutrient needs in a plant.

² Soil Management. Retrieved 05 April 2015, http://www.ctahr.hawaii.edu/mauisoil/c_relationship.aspx

³ The pH Scale – University of California, Davis. Chemwiki. Retrieved 07 April 2015, from http://chemwiki.ucdavis.edu/Physical_Chemistry/Acids_and_Bases/Aqueous_Solutions/The_pH_Scale

Section C: Nutrients

Reservoirs of nutrients exist within the soil ecosystem. These nutrients move in pathways that are referred to as the biogeochemical cycles. Essential elements that are vitally important are transferred in water or the air – and they are carbon, hydrogen, oxygen and nitrogen. Pathways for these essential nutrients and other nutrients needed for growth and development must be established in order for the nutrients to be absorbed into the plant. The pathways are driven by characteristics of the ions and capillary action. When adding nutrients into the soil, they must be in the right form and applied at the right time in order to be absorbed.

Macronutrients:

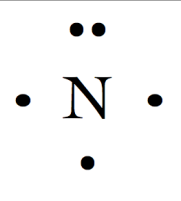
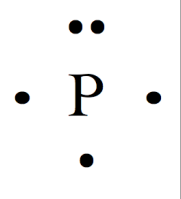
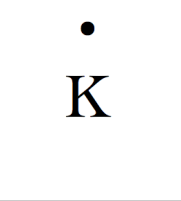
Macronutrients are needed in large quantities for proper development, hence the *macro-* in the title. The primary responsibility is for the metabolic system to function.

Primary Macronutrients																	
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn						

Nitrogen (N) makes up most of the protoplasm, makes up proteins and amino acids and is present in chlorophyll. Nitrogen (N_2) is prevalent in large quantities within the atmosphere, but most plants do not have a relationship with nitrogen fixing bacteria meaning that the plant cannot break apart the triple bond (known as “fixing”). Most plants require bacteria to convert nitrogen into a usable form in order for it to be used. Atmospheric nitrogen needs to be in the form of ammonium (NH_4^+) or nitrate (NO_3^-) in order to be used by the plant. If there is a nitrogen deficiency, it will most likely present as a purple color in the plant.

Phosphorus (P) is a structural component of deoxyribonucleic acid (DNA), Ribonucleic acid (RNA) and proteins. As a component of adenosine triphosphate (ATP), phosphorus is necessary for the conversion of light energy into chemical energy. Deficiency only becomes obvious when the plant has extremely low levels, which make scouting for this deficiency difficult.

Potassium (K) regulates the opening and closing of the stomata (minute pores), which helps in water regulation. Potassium regulates the internal moisture of a plant and the construction of carbohydrates and proteins. Wilting and browning of leaves may be an indication of potassium deficiency.

Symbol – Lewis Structure	Characteristics ⁴	Function ⁵
 <p>Nitrogen</p>	<p>Density: 1.145 g/L</p> <p>Oxidation states: -3</p> <p>Electron Shell Configuration: [He] 2s² 2p³</p>	<ul style="list-style-type: none"> • N is a structural component of chlorophyll • N is a structural component of the nucleic acids (DNA, RNA) in each cell • N is a structural component of all proteins
 <p>Phosphorus</p>	<p>Density: 1.823 g/cm³</p> <p>Oxidation states: -3</p> <p>Electron Shell Configuration: [Ne] 3s² 3p³</p>	<ul style="list-style-type: none"> • Plays a role in photosynthesis & respiration • Plays a role in seed and fruit production • Plays a role in energy production, storage, and transfer • Plays a role in cell division and enlargement
 <p>Potassium</p>	<p>Density: 0.89 g/cm³</p> <p>Oxidation states: +1</p> <p>Electron Shell Configuration: [Ar] 4s¹</p>	<ul style="list-style-type: none"> • Role in photosynthesis and plant food formation. • Role in sugar and carbohydrate production, transport, and storage. A common effect of this K function is an N shortage in legumes when they are short of K. K deficient plants produce and transport less sugar to the legume nodules, thus causing the N-fixing bacteria in the nodules to reduce the amount of N produced. • Important, in conjunction with Ca and B, in the proper development of cell walls. • Controls plant cell turgor [as it pertains to the osmotic flow of water] and through this the opening and closing of leaf stomata. This in turn controls the plants ability to effectively respond to drought stress.

Reading Questions

1. Discuss the use of the word 'reservoir' as it is used in this passage.

2. Define the term 'macronutrients' and defend the importance of these nutrients within a plant.

⁴ Welcome to Chemistry-Reference.com! (n.d.). Retrieved 16 May 2015, from <http://www.chemistry-reference.com/>

⁵ Spectrum Analytic Inc. (n.d.). Retrieved 19 May 2015, from <http://www.spectrumanalytic.com>

Secondary Macronutrients

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn						

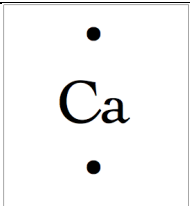
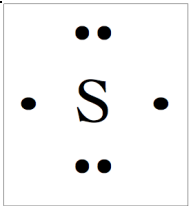
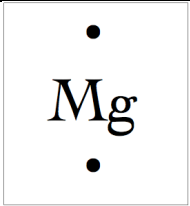
Calcium (Ca) is a main constituent of cell walls and is important in root development where it is part of cell division, cell elongation and the processing of hydrogen ions. It primarily resides in the leaves and regulates the transport of other nutrients into the plant.

Sulfur (S) is needed in the manufacturing of chloroplast and is a structural component of some amino acids and vitamins. Deficiency will affect younger tissues first. This macronutrient is absorbed primarily through the air as sulfur dioxide (SO₂) and hydrogen sulfide (H₂S).⁶

Magnesium (Mg) is part of the chlorophyll molecule and is part of numerous enzyme reactions. Deficiencies manifest themselves in older tissues first. Deficiencies occur most often in strongly acidic, light, sandy soils where magnesium can be easily leached away.⁷

⁶ Soybean Growth and Development (December 2009) Iowa State University, University Extension

⁷ Norman P.A. Huner; William Hopkins. (2009) "3 & 4". *Introduction to Plant Physiology 4th Edition*. John Wiley & Sons, Inc.
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Symbol – Lewis Structure	Characteristics ⁸	Functions ⁹
 <p>Calcium</p>	<p>Density: 1.54 g/cm³</p> <p>Oxidation states: +2</p> <p>Electron Shell Configuration: [Ar] 4s²</p>	<ul style="list-style-type: none"> • Proper cell division and elongation • Proper cell wall development • Nitrate uptake and metabolism • Enzyme activity • Starch metabolism
 <p>Sulfur</p>	<p>Density: 2.07 g/cm³</p> <p>Oxidation states: -2</p> <p>Electron Shell Configuration: [Ne] 3s² 3p⁴</p>	<ul style="list-style-type: none"> • A structural component of protein and peptides • Active in the conversion of inorganic N into protein • A catalyst in chlorophyll production • Promotes nodule formation in legumes • A structural component of various enzymes • A structural component of the compounds that give the characteristic odors and flavors to mustard, onion and garlic
 <p>Magnesium</p>	<p>Density: 1.74 g/cm³</p> <p>Oxidation states: +2</p> <p>Electron Shell Configuration: [Ne] 3s²</p>	<ul style="list-style-type: none"> • Photosynthesis: Mg is the central element of the chlorophyll molecule. • Carrier of Phosphorus in the plant • Magnesium is both an enzyme activator and a constituent of many enzymes • Sugar synthesis • Starch translocation • Plant oil and fat formation • Nutrient uptake control • Increase Iron utilization • Aids nitrogen fixation in legume nodules

Reading Questions

1. Distinguish between a primary macronutrient and a secondary macronutrient. Why is this difference significant?

⁸ Welcome to Chemistry-Reference.com! (n.d.). Retrieved 16 May 2015, from <http://www.chemistry-reference.com/>

⁹ Spectrum Analytic Inc. (n.d.). Retrieved 19 May 2015, from <http://www.spectrumanalytic.com>

Micronutrients:

Micronutrients are needed for plant growth, but only in small quantities.

Micronutrients																	
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn						

Boron (B) is required for carbohydrate metabolism, as well as the uptake and utilization of calcium. It also helps in membrane functioning, pollen germination, cell elongation and cell differentiation. Plants contain boron in both water-soluble and insoluble form. In this case, soluble boron represents a surplus of the nutrient.¹⁰

Chlorine (Cl) has a role in photosynthesis and is necessary for osmosis. An imbalance of chlorine can interfere with the uptake of phosphorus.¹¹

Manganese (Mn) is used in plants as a major contributor to various biological systems including photosynthesis, respiration, and nitrogen assimilation. Manganese is also involved in pollen germination, pollen tube growth, root cell elongation and resistance to root pathogens.¹²

Iron (Fe) is necessary for photosynthesis; however, it is not a part of chlorophyll but is essential for its synthesis. Plants uptake iron in its oxidized forms, Fe^{2+} (ferrous form) or Fe^{3+} (ferric form). Ammonium nitrogen increases proton release by roots, thus lowering pH and facilitating iron uptake, whereas nitrate nitrogen enhances the release of hydroxide ions that increase pH in the root zone and counteract efficient iron uptake. Deficiency does not always mean that there is not enough in the soil. It may also be related to various conditions that may affect iron uptake availability.¹³

Copper (Cu) is an important component of proteins found in enzymes that regulate the rate of many biochemical reactions in plants. Copper promotes seed production and formation, plays an essential role in chlorophyll formation and is essential for proper enzyme activity.¹⁴

¹⁰ Boron Deficiency. Retrieved 03 April 2015, from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2688312/>

¹¹ Roles of the 16 Essential Nutrients in Crop Development. Retrieved 03 April 2015, from <http://www.eldoradochemical.com/fertiliz1.htm>

¹² Role of Manganese in Plant Culture. Retrieved 03 April 2015, from <http://www.pthorticulture.com/en/training-center/role-of-manganese-in-plant-culture/>.

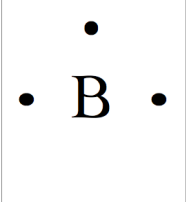
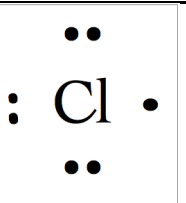
¹³ Iron Nutrition in Plants. Retrieved 03 April 2015, from <http://www.smart-fertilizer.com/articles/iron>.

¹⁴ Copper for Crop Production. Retrieved 03 April 2015, from <http://www.extension.umn.edu/agriculture/nutrient-management/micronutrients/copper-for-crop-production/>.

Molybdenum (Mo) largely occurs in the soil as an oxycomplex (MoO_4^{2-}). Because of this, molybdenum more resembles phosphate or sulfate in its behavior in the soil. In a similar way to these two anions, molybdate is adsorbed by soil minerals and colloids. Molybdenum is an essential component of two major enzymes in plants, nitrogenase and nitrate reductase. It catalyzes the reduction of NO_3^- to NO_2^- .¹⁵

Nickel (Ni) in the form of Ni^{2+} , is a component of some plant enzymes, most notably urease, which metabolizes urea nitrogen into useable ammonia within the plant. Nickel is also used as a catalyst in enzymes used to help legumes fix nitrogen.¹⁶

Zinc (Zn) plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes in many important biochemical pathways including: a) carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, b) protein metabolism, c) auxin (growth regulator) metabolism, d) pollen formation, e) the maintenance of the integrity of biological membranes, and f) the resistance to infection by certain pathogens.¹⁷

Symbol – Lewis Structure	Characteristics ¹⁸	Functions ¹⁹
 <p>Boron</p>	<p>Density: 2.34 g/cm³</p> <p>Oxidation states: +3</p> <p>Electron Shell Configuration: [He] 2s² 2p¹</p>	<ul style="list-style-type: none"> • Maintains a balance between sugar and starch. • Moves sugars and carbohydrates throughout plant. • Important in pollination and seed reproduction. • Necessary for normal cell division, nitrogen metabolism, and protein formation. • Essential for proper cell wall formation. • Plays an important role in the proper control of internal water balance through the proper function of cell membranes and the transport of K to guard cells.
 <p>Chlorine</p>	<p>Density: 2.898 g/L</p> <p>Oxidation states: -1</p> <p>Electron Shell Configuration: [Ne] 3s² 3p⁵</p>	<ul style="list-style-type: none"> • Works in tandem with K⁺ to ensure the proper function of the plants stomatal openings, thus controlling internal water balance. • Functions in photosynthesis, specifically the water splitting system. • Functions in cation balance and transport within the plant.

¹⁵ Molybdenum in Plant Nutrition. Retrieved 03 April 2015, from <http://www.albionplantnutrition.com/news/68-molybdenum-in-plant-nutrition>.

¹⁶ Role of Nickel in Plant Culture. Retrieved 03 April 2015, from <http://www.pthorticulture.com/en/training-center/role-of-nickel-in-plant-culture/>.

¹⁷ Zinc Benefits, Uses, Facts, Events & Programs. Retrieved 03 April 2015, from http://www.zinc.org/info/zinc_crops.

¹⁸ Welcome to Chemistry-Reference.com! (n.d.). Retrieved 16 May 2015, from <http://www.chemistry-reference.com/>

¹⁹ Spectrum Analytic Inc. (n.d.). Retrieved 19 May 2015, from <http://www.spectrumanalytic.com>

<div style="text-align: center;"> <p>•</p> <p>Mn</p> <p>•</p> <p>Manganese</p> </div>	<p>Density: 7.3 g/cm³</p> <p>Oxidation states: +2,3,4,6,7</p> <p>Electron Shell Configuration [Ar] 4s² 3d⁵</p>	<ul style="list-style-type: none"> • Essential for the assimilation of carbon dioxide in photosynthesis. • Aids in the synthesis of chlorophyll and in nitrate assimilation. • Activates fat forming enzymes. • Functions in the formation of riboflavin, ascorbic acid, and carotene. • Functions in electron transport during photosynthesis. • Involved in the water-splitting reaction during photosynthesis.
<div style="text-align: center;"> <p>•</p> <p>Fe</p> <p>•</p> <p>Iron</p> </div>	<p>Density: 7.87 g/cm³</p> <p>Oxidation states: +3,2</p> <p>Electron Shell Configuration: [Ar] 4s² 3d⁶</p>	<ul style="list-style-type: none"> • Essential in chlorophyll development and function. • Plays a role in energy transfer within the plant. • It is a constituent of certain enzymes and proteins. • Functions in plant respiration and metabolism. • Involved in nitrogen fixation
<div style="text-align: center;"> <p>•</p> <p>Cu</p> <p>Copper</p> </div>	<p>Density: 8.96 g/cm³</p> <p>Oxidation States: +2,1</p> <p>Electron Shell Configuration: [Ar] 4s¹ 3d¹⁰</p>	<ul style="list-style-type: none"> • Functions as a catalyst in photosynthesis and respiration. • It is a constituent of several enzyme systems involved in building and converting amino acids to proteins. • Important in carbohydrate and protein metabolism. • Important to the formation of lignin in plant cell walls which contributes to the structural strength of the cells, and the plant.
<div style="text-align: center;"> <p>•</p> <p>Mo</p> <p>Molybdenum</p> </div>	<p>Density: 10.2 g/cm³</p> <p>Oxidation states: +6,3,5</p> <p>Electron Shell Configuration: [Kr] 5s¹ 4d⁵</p>	<ul style="list-style-type: none"> • Functions in converting nitrates (NO₃) into amino acids within the plant. • Essential to the symbiotic nitrogen-fixing bacteria in legumes. • Essential to the conversion of inorganic P into organic forms in the plant.
<div style="text-align: center;"> <p>•</p> <p>Ni</p> <p>•</p> <p>Nickel</p> </div>	<p>Density: 8.90 g/cm³</p> <p>Oxidation states: +2,3</p> <p>Electron Shell Configuration: [Ar] 4s² 3d⁸</p>	<ul style="list-style-type: none"> • Promotes and boosts the plant's resistance to preventing the penetration and reproduction of invading pathogens or pests. • Nickel goes throughout the plant system and boosts the processes of disease management²⁰
<div style="text-align: center;"> <p>•</p> <p>Zn</p> <p>•</p> <p>Zinc</p> </div>	<p>Density: 7.14 g/cm³</p> <p>Oxidation states: +2</p> <p>Electron Shell Configuration: [Ar] 4s² 3d¹⁰</p>	<ul style="list-style-type: none"> • Essential for the production of Auxins, an essential growth hormone. • Activates enzymes in protein synthesis, • Involved in the regulation and consumption of sugars • Necessary for starch formation and proper root development. • Influences the rate of seed and stalk maturation. • Necessary for the formation of chlorophyll and carbohydrates. • Adequate amounts in the tissue enables the plant to withstand lower air temperatures.

Reading Questions

1. Compare and contrast macronutrients and micronutrients.

[illegible]