THE WONDER OF PLANTS

The practice of plant husbandry began with early man. Even before we had the slightest concept of plant physiology, it was observed that certain conditions had an influence on plant health and vigor. Eventually we began to select and organize desirable plant types and contribute to their basic requirements. We suspected that there was something in the soil that plants consumed but it took thousands of years to stumble upon even the most basic understanding of the science of plant chemistry. Only in the last one hundred years has technology advanced to the point that we can accurately measure and manipulate a plants internal functions. And even more recently isolate and identify plant substances genetically and at an atomic level. This knowledge has allowed us to breed and propagate specialized flower, food, and resource crops, more prolific and abundant then ever before. We must use good judgement because our ability to alter the natural way of things is a power not to be used haphazardly.

Our goal is to provide select and precise constituents to a plant growth environment, in a properly balanced manner, neither lacking or in excess. Most people realize that living plants are a complex organism, whose internal functions are generally taken for granted. Some people seem to have a sense of awareness and unity with plants, while others simply see an inanimate object.

What do you see? Do you see water and minerals moving across and into the roots, and traveling through stem and branches into living leaf cells? Or the water molecules evaporate out through the open leaf stomates? Do you see the CO_2 molecules diffusing into the chloroplasts, and then being fixed by photosynthesis into carbohydrates which then travel by vascular pathways to all points of demand? Do you see the ions from essential minerals being selectively absorbed and combined into coenzymes and organic compounds? Do you see the nourished cells split and reproduce to form the splendor of foliage and flower we see before us? Of course not, but it is happening, and we can gain at least a sense of awareness that it is.

A plant, as any living organism, is a marvel of chemistry, yet it operates much like a machine, governed by the laws of physics. This being the case it stands to reason that anyone can learn to grow plants. Especially with the technology and automated systems available today. Maybe it's not necessary to understand the internal workings of a plant to successfully manage a growing operation and produce plentiful crops.

The properties of air and water and the substances dissolved in them begins the miracle of plant physiology. There is what seems a dimensionless symphony of chemistry occurring at a molecular level all around us. Plant systems are dependent upon these basic constituents: light/heat, CO_2 water, and essential minerals. As growers, our task is to provide all of these requirements in a plentiful and properly balanced fashion. This booklet will deal primarily with functions related to nutrient assimilation and the management practices necessary to maintain ample solution properties. We will address the concern of fluid as a means of translocating nutrient elements into the plant and its cell structures. We will touch on some of the fundamentals of plant physiology and attempt to address some of the most frequently misunderstood aspects of plant science.

PLANT COMPOSITION

Plants consist of a complex arrangement of cell bodies working together, each in their own way to form a living organism. These cells are made up of, or contain many components such as proteins, polysaccharides, amino and organic acids, lignin's etc. These compounds are themselves comprised of principle elements which over 80% (as dry weight) consist of oxygen and carbon. Followed respectively in quantitative sequence is hydrogen, nitrogen, silicon, potassium, calcium, sulfur, phosphorus, magnesium, aluminum, iron, chlorine, sodium, manganese, boron, copper, zinc, molybdenum and other assorted scarce minerals. Different combinations of these constituents form molecules of many identities to construct new cells and tissues. This is why these essential elements must be readily available. These sixteen elements, along with water and sunlight, plants are able to synthesize all the compounds they require, as well as, vitamins and enzymes necessary to us as consumers. These essential elements can be provided in their elemental form, pure and immediately available, with the application of high quality inorganic fertilizers. These essential elements can also be found in organic molecules (such as found in soils) however, organic materials must be broken down into their pure elemental (inorganic) form before they can be utilized by the plant. Additional energy is required to disassociate these more complex organic commodities. Plants will absorb and accumulate numerous nonessential elements. Plants can uptake, breakdown, or retain many substances. If these substances are beneficial it could be desirable but if they are toxic it could be disastrous. Many elements have been found in plant tissue which are not known to have any influence on plant metabolism. Lead, arsenic, mercury, gold and fluoride are among the more than 60 other known elements.

THE MYSTERY OF ROOTS

Roots not only provide a means of support, but they act as receptors providing pathways for select solutions and substances to be regulated into the plants circulatory systems. Root anatomy consists primarily of a xylem and phloem core of vascular tissue, surrounded by a cortex tissue and an outer layer of epidermal tissue. Microscopic projections called root hairs usually develop on the epidermal cell to further enhance the water absorption capability of the root surface. These follicles are very delicate and should be protected from dryness, extreme temperatures, harsh chemicals or abrasion. Root health is vital, as the survival of the whole plant depends on it.

Roots are specially adapted tissues which readily absorb aqueous substances and transport them into the plants main vascular system. This vascular network originates at the tips of the roots and is continuous throughout the plant. Absorption is supported by the process of diffusion. Diffusion is the process by which ions and molecules distribute uniformly throughout a contiguous volume. Nutrient ions will diffuse into the root, between it's cells, through intercellular spaces called the apoplast, and interconnecting protoplasm called the symplast. These pathways allow water and solutes to pass across the cortex and through the endodermal layer and into the vascular bundles. Xylem and phloem bundles guide solutions through the plants roots and stem. The xylem tissue forms the vessels that channel solutions up into the plant and the phloem tissues primarily distribute internally manufactured foods throughout the plant. Once in the main phloem it is transferred to all parts of the plant. All plant cells, each with a different appetite, will be exposed to these fluids and accumulate the nutrients they require to achieve their assigned functions.

PLANT SOLUTION TRANSPORT

The movement of solution through the plant is a complex combination of internal and external forces. This force is then used by the plant in a variety of ways, some of which include:

1. To deliver essential substances to the various internal mechanisms as well as removing waste products.

2. To provide systemic pressure to give the plant structural integrity.

3. To facilitate cooling of plant tissues by transfer and evaporation.

Solutions travel throughout the plants leaves and stems via capillary channels called veins. These vascular bundles perform two modes of transport. First to deliver water and nutrients to all cellular tissues for assimilation and second to translocate manufactured food substances (photosynthates) from the point of photosynthesis to all parts of the plant (flowers, fruit, meristems, etc.). These conduits are called the xylem and the phloem tissues.

Many factors play a role in moving solutions through the plant's circulatory system: absorption, capillary action, cohesion, menisci, hydration and root pressure, to mention a few. The combination of these forces serves to propel solution up and throughout the plant. Transpiration is the major contributor to this process. Simply put, it is the affinity of dry air to obtain water vapor. As the air removes water from the leaf, it literally draws more up into the plant to replace it. This captivation relies upon the cohesion of water molecules (a term for the attraction of one water molecule for another) which literally pulls water up the plants vascular capillaries like a chain. These fluids are the life blood of the plant and must be available consistently for good health. The use of a high quality plant nutrient will assure that the transport system will function properly.

NUTRIENT ASSIMILATION

Within a plant's structure exist many types of cells. These cells vary in their ability to absorb solutes by the nature of their membranes. A solute could be anything dissolved in a solvent (water). Membranes are thin permeable tissues which surround the cell bodies. These cell membranes are designed to be specific to which elements are able to pass through them. The following forces control this flow (flux) process.

1. Osmosis is the tendency for a solvent (in our case water) to pass through a membrane from the side of less soluble salts to the side of higher concentration. It is attempting to dilute the solution to gain equilibrium on each side. This action is regulated by particle concentration, not by their properties. When this activity is measured it is termed the chemical potential.

2. The second type of membrane flow is called the electrical potential. This force is driven by the exchange of positive (cation) and negative (anions) ions creating a + or - potential within the cell. A positive affinity will generally attract negative ions to balance its polarity (and vise versa). This creates a flow of ions by electrical attraction.

3. Another method involves the use of a carrier molecule, often part of the membrane itself. If an ion is attracted to a site on a carrier molecule, it may then diffuse readily across the membrane to be released on the other side. This method controls ion selectivity by the ability of the carrier to combine with a specific element ion. This explains why only certain ions are able to pass through a given membrane tissue type.

Many factors and conditions effect these processes and their ability to absorb essential elements. Among these are, nutrient solution concentration, balance, pH, temperature, or the presence of incompatible chemicals which may bind and inhibit important minerals from being available to the plants.

ORGANIC FERTILIZATION

The scientific definition of organic is "any chemical compound containing carbon". A more common interpretation is any substance derived from living organisms, plant or animal. The concept of organic gardening usually implies that, the essential elements required for plant nutrition will be attained by dissociation from decomposing matter. This process occurs in nature when a plant or animal expires or sheds tissue which is then systematically acted upon by organisms and environmental conditions. These influences range from abrasion, dissolution, combustion, chemical reduction, to consumption by man or animals. When organic matter is consumed and digested by microorganisms (primarily bacterium), it is broken down and released as enzymes of proteins, starches, vitamins, hormones and other such metabolites. Some of these compounds can be taken up into the plant and stored, or selectively utilized by the plant for metabolic functions. These processes of plant chemistry are very complex electrochemical interactions which take place in a series of stages, in an infinite chain of events not yet fully defined by science. The end result of all of this is to provide pure inorganic elements which are the building blocks of all life.

INORGANIC FERTILIZATION

The term "inorganic" defines a substance as a non-living material neither of plant or animal origin. Generally referring to matter not containing carbon. All organic structures are composed of inorganic compounds and will eventually degrade back to this original form. Pure inorganic elements and combinations thereof, are the foundation of all living things (and otherwise) on this planet. The mysterious interactions of these 103 elements somehow manages to create or at least sustain life and all things of substance.

When used in a horticultural context, it describes the type of feeding program which utilizes basic elemental complexes as mineral salts. About fifteen (15) of these elements are known to be essential for normal plant growth. When these elements are in solution they become available (to some degree) for plants to assimilate, either in their pure form or as ions of simple compounds. All essential substances necessary for plant functions can be manufactured by the plant from these inorganic elements. When these elements are combined into compatible compounds, they are referred to as chemical fertilizers. These carefully balanced nutrient blends allow us to provide, pure and precise allocations of mineral elements and encourage the type of plant response desired. Hydroponic techniques have proven that pure elemental solutions are the most dependable and predictable way to insure optimum productivity. These methods allow us to totally isolate and contain a complete grow system. Solutions may be circulated and recovered and re-proportioned for subsequent use. This can mean tremendous benefits in terms of ecology, productivity, economy, and application. These methods can provide food for people in areas where conventional farming methods would not be possible.

Chemical fertilizers have undeservingly been given a bad rap because they have been associated with large scale wasteful misuse. This has resulted in the contamination of soils and water supplies. This is not the fault of the chemical, rather the management thereof. Another unfair association is that of pesticides, fungicides, herbicides, inoculates, and preservatives etc., of which chemical fertilizers have no relationship. Chemicals compounds are not undesirable just because it has been refined or combined by man.

NUTRIENT PROPERTIES

Each of the elements essential for plant growth perform a distinct function in the metabolism process. Their fundamental properties will be described in the following paragraphs.

Nitrogen

These ions provide nitrogen and are usually found in low concentrations in ground water. Levels above 10 ppm are undesirable for drinking purposes. Most plants can utilize levels between 100 and 400 ppm.

Nitrate - Ammonium is found in both inorganic and organic forms in the plant, and combines with carbon, hydrogen, oxygen and sometimes sulfur to form amino acids, amino enzymes, nucleic acids, chlorophyll, alkaloids, and purine bases. Nitrogen rates high as molecular weight proteins in plant tissue. Deficiencies exhibit slow growing, weak and stunted plants with light green to yellow older leaves. Quality and yield will be significantly reduced. Excess conditions will be dark green and succulent with breakdown of vascular tissue restricting water uptake. Stress resistance is drastically diminished.

Silicon

Silicon usually exists in solution as silicic acid and is absorbed in this form. It accumulates as hydrated amorphous silica most abundantly in walls of epidermal cells, but also in primary and secondary walls of other cells. It is largely available in soils and is found in water as well. Inadequate amounts of silicon can reduce tomato yields as much as 50%, cause new leaves to be deformed and inhibit fruit set. At this time toxicity symptoms are undetermined.

Hardness

Water Hardness is an indication of the calcium and magnesium content. Moderately hard water, 100 to 150 mg CaC03 / liter is desirable for plant growth. If the water is very soft, less than 50 mg, you may need to provide supplemental calcium and magnesium.

Potassium and Phosphate

These essential plant macro-nutrients normally occur in very low concentrations in water. If the water contains more than a few ppm of these elements there is a possibility that your water may contain fertilizer, detergent or other contaminants.

Potassium is involved in maintaining the water status of the plant and the tugor pressure of it's cells and the opening and closing of the stomata. Potassium is required in the accumulation and translocation of carbohydrates. Lack of potassium will reduce yield and quality. Older leaves will be scorched on edges. Plant will become susceptible to disease and toxicity. Excesses will interfere with magnesium and calcium availability.

Phosphorus is a component of certain enzymes and proteins, adenosine triphosphate (ATP), ribonucleic acids (RNA), deoxyribonucleic acids (DNA) and phytin. ATP is involved in various energy transfer reactions, and RNA and DNA are components of genetic information. Deficiencies exhibit slow growing, weak and stunted plants with dark green or purple pigmentation in older leaves and stems. Excess will interfere with iron and zinc stability in solution.

Calcium - Magnesium - Sulfate

These ions may be present in high levels in ground water. It is important to consider these values when adding nutrient supplements.

Calcium plays an important role in maintaining cell integrity and membrane permeability. Deficiency will cause root tip die-back, leaf tip curl and marginal necrosis and chlorosis primarily in younger leaves. Blossom end rot and internal decay may also occur. Excess calcium may produce deficiencies in magnesium and potassium.

Magnesium is a component of the chlorophyll molecule and serves as a cofactor in most enzymes. Deficiency will exhibit a yellowing and interveinal chlorosis beginning in the older leaves. Extreme high levels will antagonize other ions in the nutrient solution.

Sulfate is involved in protein synthesis and is part of the amino acids, cystine and thiamine, which are the building blocks of proteins. It is active in the structure and metabolism in the plant. It is essential for respiration and the synthesis and breakdown of fatty acids. Sulfur deficiencies are light green fruit or younger leaves with a lack of succulence. Elongated roots and woody stem. Excess may cause early senescence.

Sodium - Chloride

If the water contains high levels of chloride, it will usually have high levels of sodium, however the reverse is not true. Many waters can contain significant amounts of sodium without containing high levels of chloride.

Sodium seems to encourage crop yields and in specific cases it acts as an antidoting agent against various toxic salts. It may act as a partial substitute for potassium deficiencies. Excess may cause plant toxicity or induce deficiencies of other elements. If sodium predominates in the solution calcium and magnesium may be affected.

Chloride is involved in the evolution of oxygen in the photosynthesis process and is essential for cell division in roots and leaves. Chlorine raises the cell osmotic pressure and affects stomata regulation and increases the hydration of plant tissue. Levels less than 140 ppm are safe for most plants. Chloride sensitive plants may experience tip or marginal leaf burn at concentrations above 20 ppm. Plants with chlorine deficiencies will be pale and suffer wilting. Excesses will cause burning of tips and margins, and bronzing and abscission of the leaves.

Micro Nutrients

This minor elements section discusses elements typically found in water and often added as additions in nutrient solutions. These values will normally be very low. Consider the accumulated concentration of these elements in the media, fertilizer and water.

Boron

Boron biochemical functions are yet uncertain, but evidence suggests it is involved in the synthesis of one of the bases for nucleic acid (RNA uracil) formation. It may also be involved in some cellular activities such as division, differentiation, maturation and respiration. It is associated with pollen germination. Plants deficient in boron exhibit brittle abnormal growth at shoot tips and one of the earliest symptoms is failure of root tips to elongate normally. Toxicity will cause yellowing before leaves die and prematurely fall off.

Copper

Copper is a constituent of many enzymes and proteins. Assists in carbohydrate metabolism, nitrogen fixation and in the process of oxygen reduction. Symptoms of deficiency are a reduced or stunted growth with a distortion of the younger leaves and growth tip die-back. Copper is required in very small amounts and readily becomes toxic in solution culture if not carefully controlled. Excess values will induce iron deficiency. Root growth will be suppressed.

Iron

Iron is an important component of plant enzyme systems for electron transport to carry electrons during photosynthesis and terminal respiration. It is a catalyst for chlorophyll production and is required for nitrate and sulfate reduction and assimilation. Interveinal chlorosis of younger leaves is the typical symptom of deficiency. Excess accumulation is rare but could cause bronzing or tiny brown spots on leaf surface.

Manganese

Manganese is involved in the oxidation reduction process in the photosynthetic electron transport system. Biochemical research shows that this element plays a structural role in the chloroplast membrane system, and also activates numerous enzymes. Interveinal chlorosis of younger leaves, necrotic lesions and leaf shredding are typical symptom of this deficiency. High levels can cause uneven distribution of chlorophyll resulting in blotchy appearance.

Zinc

Zinc plays a roll in the same enzyme functions as manganese and magnesium. More than eighty enzymes contain tightly bound zinc essential for their function. Zinc participates in chlorophyll formation and helps prevent chlorophyll destruction. Carbonic anhydrate has been found to be specifically activated by zinc. Deficiencies appear as chlorosis in the interveinal areas of new leaves producing a banding appearance. Branch terminals of fruit will die back in severe cases. Excess will cause sensitive plants to become chlorotic.

Cobalt

Cobalt is essential to many beneficial bacteria that are involved in nitrogen fixation of legumes. It is a component of vitamin B12 which is essential to most animals and possibly in plants. Reports suggest that it may be involved with enzymes needed to form aromatic compounds. Otherwise, it is not understood fully as to its benefit to plant growth, but it is considered essential to some animal health issues.

Molybdenum

Molybdenum is a component of two major enzyme systems involved in the nitrate reeducates, this is the process of conversion of nitrate to ammonium. Moly-deficiencies frequently resemble nitrogen, with older leaves chlorotic with rolled margins and stunted growth. Excess moly usually does not effect the plant, however the consumption of high levels by grazing animals can pose problems.

Fertilizer Interpretation

Fertilizer formulations are defined and listed by manufacturers in percentages, and termed the "guaranteed analysis". The law requires these values be presented in a somewhat ambiguous fashion, for reasons nobody seems to remember. First on the label, are the percentages for the nitrogen, phosphorus, and potassium (NPK). They are rounded down to the next whole number. The nitrogen (N) is given as total combined elemental nitrogen, and is further defined as nitrate (NO_3) or ammonium (NH_4). Phosphorus is listed as phosphoric anhydride (P_2O_5), when the actual phosphorus (P) is less than 44% of that figure. The remaining 56% of that molecule is oxygen. Example: 10% P_2O_5 is only 4.4% as P. Potassium is listed as potash (potassium oxide) or (K_2O), and only 83% of the listed value is actual elemental potassium (K). All other minerals are listed as elemental and should represent actual content. Below the guaranteed analysis, will be a list of compounds which were used in this formula and contain, at minimum, the values listed. However, just because a mineral is in content, does not assure that it is in a form free and available to the plant. These must otherwise be defined as water soluble. Inferior or improperly combined nutrient compounds can render some of the listed elements useless for immediate assimilation.

Nutrient values, though listed as percentages, are generally measured in parts per million (ppm). This is to say, that there is one part of a given substance to each 999,999 parts of all other content. In other words, if you divide what ever you have into one million pieces, one of them would be one ppm. To convert percentage to ppm, multiply by 10,000, or move the decimal 4 spaces to the right. Example: 1% = 10,000 ppm.

Nutrient Solutions

Check solution level. Sufficient quantity must be available to maintain stable solution properties. A small reservoir will require more frequent amendments to keep the nutrient concentrations and pH within the acceptable range. The two most important of these properties is, ionic strength and acid balance. Respectively, the concentration of soluble salts (nutrient elements) and the pH, which is the acid/ base balance that regulates the interactions and availability of these elements.

Fertilizer Concentration

Fertilizer concentrations can be easily measured with inexpensive electronic meters. Element concentrations can be measured by their ability to conduct electricity through a solution. Since every element in a multi-element solution has a different conductivity factor, these measurements are only approximate. Pure water will not conduct current, but as you add elemental salts (mostly metals) conductivity increases proportionately. Simple electronic meters can measure this value and interpret it as total dissolved solids (TDS). Nutrient solution concentrations suitable for plant nourishment generally range between 500 and 2000 parts per million (ppm).If the solution concentration is to high, the internal osmotic systems can reverse and actually dehydrate the plant. For general purpose, try to maintain a moderate value of approximately 800 to 1200 ppm. These levels can be effected by plant absorption or by water evaporation. As the plants use the nutrients, the solution weakens, but as the water evaporates from the solution, the salt concentration increases. Adjust values by either adding fertilizer or diluting with water. Use luke warm water and try to maintain a solution temperature between 60 and 80 degrees. Use a complete and soluble high quality hydroponic fertilizer according to recommendations on label.

Nutrient Solution pH

Solution pH (potential hydrogen) is extremely critical and must be checked often to maintain a nearly neutral balance. Variations either way will effect the breakdown and solubility of the nutrient compounds. Acceptable values vary slightly with different plants, grow mediums, and hydroponic systems. Generally desirable readings range from 5.5 (slightly acid) to 7.0 (neutral). For general purposes, try to maintain a value of 6.5 and make a correction if readings vary +/- a half point. The tolerance range therefore is 6.0 to 7.0 . Use pH up and down adjusters carefully and mix in slowly and completely. Fertilizers, when added will usually lower the solutions pH value. Most of the time, as solutions are used by plants, the pH will raise, and additions of fertilizer, or a pH down adjuster will be needed. It is preferable to adjust water pH before adding fertilizer, once you are familiar with what adjustments will be required. Solution pH can be determined either by a reagent color comparison method or with an electronic test meter.

Solution Maintenance

Solutions can be topped off and corrected in a casual routine (usually for about 30 days) at which point they should be replenished with a fresh supply. Meanwhile, keep the solution water level constant and use an electronic conductivity meter to determine how much additional fertilizer will need to be provided. Tanks, trays and plumbing should be cleaned and rinsed periodically to remove algae, excess nutrient salts, and possible viral or fungal pathogens. A 5% sodium hypochlorite solution (bleach) should be used to sterilize the system between crops. Monthly leaching (rinsing) of substrate (grow medium) by clear watering is advised to reduce accumulation of soluble salts, and avoid a toxic build up of immobile trace elements.

Solution pH

Solution pH (potential hydrogen) controls the availability of ions to be assimilated into the plant. Solution pH is displayed on a scale from 0 to 14 with 7 being neutral. All values less are considered acidic, and all values greater are alkaline. Plant solutions are generally considered desirable between 6.0 and 7.0 pH.

Nutrient Solution Composition

The values below provide a guideline of acceptable limits. Values deficient or in excess of those shown could result in poor plant health.

Values generally considered desirable for elements in nutrient solutions as ppm.

Nutrient Solution Composition

ELEMENT	LIMITS	AVERAGE
Nitrogen	150-1000	250
Calcium	100-500	200
Magnesium	50-100	75
Phosphorus	50-100	80
Potassium	100-400	300
Sulfur	200-1000	400
Copper	0.1-0.5	.05
Boron	0.5-5.0	1.0
Iron	2.0-10	5.0
Manganese	0.5-5.0	2.0
Molybdenum	0.01-0.05	0.02
Zinc	0.5-1.0	0.5

Soluble Salts Range Chart
Electrical conductivity (EC)as millisiemen (mS) and total dissolved solids (TDS) as parts per million (PPM)

Soluble Salts Range Chart

Electrical conductivity (EC)as millisiemen (mS) and
total dissolved solids (TDS) as parts per million (PPM)

RANGE	EC as mS	TDS as PPM
DESIRABLE	0.75 to 2.0	500 to 1300
PERMISSIBLE (with potential for concern)	2.0 to 3.0	1300 to 2000
PROBABLE SALT DAMAGE	3.0 and up	2000 and up

For nutrient solutions determinations
one (1) mS (millisiemen) or one mMho/cm2 is equivalent to
approximately 650 ppm total dissolved solids.

Deficiencies and Toxicity
Mobile elements
Mobile elements are more likely to exibit visual deficiencies in the older leaves, because during demand these elements will be exported to the new growth.

Nitrogen
Deficiency: Plants will exhibit lack of vigor as older leaves become yellow (chlorotic) from lack of chlorophyll. Chlorosis will eventually spread throughout the plant. Stems, petioles and lower leaf surfaces may turn purple.

Toxicity:Leaves are often dark green and in the early stages abundant with foliage. If excess is severe, leaves will dry and begin to fall off. Root system will remain under developed or deteriorate after time. Fruit and flower set will be inhibited or deformed.

Phosphorus
Deficiency:Plants are stunted and older leaves often dark dull green in color. Stems, petioles may turn purple. Plant maturity is often delayed.

Toxicity:This condition is rare and usually buffered by pH limitations. Excess phosphorus can interfere with the availability of copper and zinc.

Potassium
Deficiency:Older leaves are initially chlorotic but soon develop dark necrotic lesions (dead tissue). First apparent on the tips and margins of the leaves. Stem and branches may become weak and easily broken.

Toxicity:Usually not absorbed excessively by plants. Excess potassium can aggravate the uptake of magnesium, manganese, zinc and iron.

Magnesium
Deficiency:The older leaves will be the first to develop interveinal chlorosis. Starting at leaf margin or tip and progressing inward between the veins.

Toxicity:Magnesium toxicity is rare and not generally exhibited visibly.

Zinc
Deficiency:Chlorosis may accompany reduction of leaf size and a shortening between internodes. Leaf margins are often distorted or wrinkled.

Toxicity:Zinc in excess is extremely toxic and will cause rapid death. Excess zinc interferes with iron causing chlorosis from iron deficiency.

Immobile elements
Immobile elements will show their first symptoms on younger leaves and progress to the whole plant.

Sulfur
Deficiency:The initial symptoms are the yellowing of the entire leaf including veins usually starting with the younger leaves. Leaf tips may yellow and curl downward.

Toxicity:Leaf size will be reduced and overall growth will be stunted. Leaves yellowing or scorched at edges.

Calcium
Deficiency:Young leaves are affected first and become small and distorted or chlorotic with irregular margins, spotting or necrotic areas. Bud development is inhibited and root may be under developed or die back. Fruit may be stunted or deformed.

Toxicity:Difficult to distinguish visually. May precipitate with sulfur in solution and cause clouding or residue in tank.

Iron
Deficiency:Pronounced interveinal chlorosis similar to that caused by magnesium deficiency but on the younger leaves.

Toxicity:Excess accumulation is rare but could cause bronzing or tiny brown spots on leaf surface.

Manganese
Deficiency:Interveinal chlorosis on younger or older leaves followed by necrotic lesions or leaf shedding. Restricted growth and failure to mature normally can also result.

Toxicity:Chlorosis, or blotchy leaf tissue due to insufficient chlorophyll synthesis. Growth rate will slow and vigor will decline.

Chlorine
Deficiency:Wilted chlorotic leaves become bronze in color. Roots become stunted and thickened near tips.

Toxicity:Burning of leaf tip or margins. Bronzing, yellowing and leaf splitting. Reduced leaf size and lower growth rate.

Boron
Deficiency:Stem and root apical meristems often die. Root tips often become swollen and discolored. Internal tissues may rot and become host to fungal disease. Leaves show various symptoms which include drying, thickening, distorting, wilting, and chlorotic or necrotic spotting.

Toxicity:Yellowing of leaf tip followed by necrosis of the leaves beginning at tips or margins and progressing inward. Some plants are especially sensitive to boron accumulation.

Copper
Deficiency:Young leaves often become dark green and twisted. They may die back or just exhibit necrotic spots. Growth and yield will be deficient as well.

Toxicity:Reduced growth followed by symptoms of iron chlorosis, stunting, reduced branching, abnormal darkening and thickening of roots. This element is essential but extremely toxic in excess.

Molybdenum
Deficiency:Often interveinal chlorosis which occurs first on older leaves, then progressing to the entire plant. Developing severely twisted younger leaves which eventually die.

Toxicity:Excess may cause discoloration of leaves depending on plant species. This condition is rare but could occur from accumulation by continuous application. Used by the plant in very small quantities.

For a more complete version of the Plant Nutrition Booklet go to our old site:

http://www.greenair.com/old/plantlnk.htm

For Advanced Formula Charts see:

http://www.greenair.com/old/chart.htm

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