

Managing the Plant Environment 3

(updated October 2008)

There are factors other than pests that affect optimum plant performance, such as:

- light, temperature, water, and air,
- nutrient levels and balances,
- planting media,
- pollution and chemical injury, and
- mechanical injury.

In many cases, weakening of plants due to problems with these factors can predispose them to disease and insect problems. For this reason, it is important to be aware of the specific needs and sensitivities of each crop.

Principle of Limiting Factors

In any crop system, the level of production can be no greater than the genetic potential of the plants. However, the full genetic potential is often not realized due to some other limiting factor. The most limiting factor will determine how much of a plant's genetic potential can be realized. For instance, if nitrogen is in short supply, it will limit crop growth even though the other inputs (e.g. light and water) are in abundance.

A good cropping strategy should aim to maximize and exploit the full potential of the crop by providing optimum amounts of all of the factors required for growth, and by applying these inputs in a cost effective and environmentally responsible manner.

Temperature

Generally, the warmer the air temperature, the faster a plant will grow and develop, assuming all other conditions are optimum. Plant leaf temperatures are related to light levels and air temperature, and are regulated by transpiration. Sudden changes in air temperature will affect humidity and transpiration rates, and can result in plant stress, and unwanted condensation on leaves and greenhouse surfaces.

The difference between day and night temperature is as important as the actual temperature values. The processes that produce food for plants to grow and develop (photosynthesis) stop working at about 35°C and above. The processes that make the plant grow and develop (respiration) continue at night. At a certain low temperature (specific to the crop) these processes will also stop.

Recent research has brought about a re-thinking of greenhouse temperature control. Researchers have found that high night/low day temperatures will reduce or eliminate the need to apply plant growth regulators for certain plant species such as chrysanthemums, lilies, and poinsettias.

The technique of temperature control of plant height is based on the concept of average temperature. Plants grow and develop at a rate dependent on the average temperature they receive over the 24 hour period.

Average Temperature = $[(\text{day temp} \times \text{hrs day}) + (\text{night temp} \times \text{hrs night})] \div 24$

If plants are behind schedule, the daily average temperature can be raised to speed up development. If plants are ahead of schedule, the daily average temperature can be lowered to slow down development.

Plant height is influenced by the difference (DIF) between day and night temperature. A positive DIF (higher day than night) will produce taller plants. A negative DIF (higher night than day) will produce shorter plants. Plant height can be decreased by lowering the day temperature and also by increasing the night temperature. It can also be decreased by introducing a relatively cooler temperature, or DIP for two hours starting just before sunrise. DIP and DIF affect the length of the stem internodes rather than the number of leaves.

If plants are behind schedule, then raise the daily average temperature to speed up development. If plants are ahead of schedule, then lower the daily average temperature to slow down development.

Table 3.1: Day and Night Temperatures Needed to Produce Various Average Daily Temperatures

Temperature °C		Average Daily Temperature °C					
Day	Night	9 Hr Day	10 Hr Day	11 Hr Day	12 Hr Day	13 Hr Day	14 Hr Day
12	12	12.0	12.0	12.0	12.0	12.0	12.0
14	12	12.8	12.8	12.9	13.0	13.1	13.2
16	12	13.5	13.7	13.8	14.0	14.2	14.3
18	12	14.3	14.5	14.8	15.0	15.3	15.5
20	12	15.0	15.3	15.7	16.0	16.3	16.7
22	12	15.8	16.2	16.6	17.0	17.4	17.8
12	14	13.3	13.2	13.1	13.0	12.9	12.8
14	14	14.0	14.0	14.0	14.0	14.0	14.0
16	14	14.8	14.8	14.9	15.0	15.1	15.2
18	14	15.5	15.7	15.8	16.0	16.2	16.3
20	14	16.3	16.5	16.8	17.0	17.3	17.5
22	14	17.0	17.3	17.7	18.0	18.3	18.7
12	16	14.5	14.3	14.2	14.0	13.8	13.7
14	16	15.3	15.2	15.1	15.0	14.9	14.8
16	16	16.0	16.0	16.0	16.0	16.0	16.0
18	16	16.8	16.8	16.9	17.0	17.1	17.2
20	16	17.5	17.7	17.8	18.0	18.2	18.3
22	16	18.3	18.5	18.8	19.0	19.3	19.5
12	18	15.8	15.5	15.3	15.0	14.8	14.5
14	18	16.5	16.3	16.2	16.0	15.8	15.7
16	18	17.3	17.2	17.1	17.0	16.9	16.8
18	18	18.0	18.0	18.0	18.0	18.0	18.0
20	18	18.8	18.8	18.9	19.0	19.1	19.2
22	18	19.5	19.7	19.8	20.0	20.2	20.3
12	20	17.0	16.7	16.3	16.0	15.7	15.3
14	20	17.8	17.5	17.3	17.0	16.8	16.5
16	20	18.5	18.3	18.2	18.0	17.8	17.7
18	20	19.3	19.2	19.1	19.0	18.9	18.8
20	20	20.0	20.0	20.0	20.0	20.0	20.0
22	20	20.8	20.8	20.9	21.0	21.1	21.2
12	22	18.3	17.8	17.4	17.0	16.6	16.2
14	22	19.0	18.7	18.3	18.0	17.7	17.3
16	22	19.8	19.5	19.3	19.0	18.8	18.5
18	22	20.5	20.3	20.2	20.0	19.8	19.7
20	22	21.3	21.2	21.1	21.0	20.9	20.8
22	22	22.0	22.0	22.0	22.0	22.0	22.0

A table of day/night temperature combinations and their effect on average daily temperature is included for those growers who may wish to experiment with this technique (Table 3.1). Keep in mind that the threshold temperatures necessary for proper growth and flower induction for specific crops still apply.

Accurate temperature control is important for optimum plant performance. High temperature injury results in tissue collapse due to desiccation or overheating of cellular fluids and is more prevalent on young tissues and at leaf margins.

Unless freezing occurs, low temperature problems are more subtle. Slow growth, chlorosis of the leaves, defoliation, and various nutritional and pathogenic diseases often occur after plants are exposed to low temperatures. When propagating plants, the soil temperature must be monitored, since the rooting medium is often cooler than the air temperature due to evaporative cooling. Low temperatures can slow the growth of seedlings, or the rooting of cuttings. A sudden rise in air temperature may result in moisture condensing on leaf surfaces, providing conditions favourable to some plant diseases.

Light

Light intensity, quality, and duration are important for optimum plant growth and development. Generally, plants grow more with blue light because each unit contains more energy than red light. Plants need red light for timing their daily and seasonal clocks. Many growers have successfully used supplemental lighting to increase the light intensity during cloudy days and during the fall, winter and spring (see Table 3.2). For more information on light measurements, see *Light Measurement Conversions*, Appendix C.

Greenhouse plants may be divided into two broad groups: those tolerant of full sun and those requiring partial shading. Insufficient light levels can result in poor colouration, leggy growth, and slow

development. Excessive light causes bleaching of foliage in sensitive crops and, in severe cases, high temperature injury, since light radiation raises the leaf temperature. Problems associated with high light levels can be corrected by proper spacing, timely watering, and shading when necessary.

The acclimatization of tropical plants to maintenance levels is done over a 3 to 6 week period. This involves lowering the intensity and adjusting the duration of light to similar levels encountered in indoor plantings. When plants do not undergo this gradual change, leaf yellowing and leaf drop usually occur. Acclimatization also requires adjusting the fertilizer rates to 10 to 20 percent of original levels and adjusting soil moisture according to the size of plant, ambient humidity, air movement, and temperature.

Table 3.2: Common Supplemental Light Intensities for Various Ornamental Crops (Using High Pressure Sodium Vapour Lights)*

Crop	W/m ² (PAR)	Intensity (klux)	Foot Candles	Daylength (Hours)	Stage of Crop	Comments
Alstroemeria	6	2.16	200	13	Flowering	13+ hrs will promote flowering
African Violets	6	2.16	200	18	Stock Plants	
Bedding Plants	12	4.40	400	18	Seedlings	Will prevent stretching on cloudy days
Begonias, Fibrous	6	2.16	200	18	Seedlings	Avoid high light intensities
Begonias, Rieger	6	2.16	200	14	Stock	
Bromeliads	6	2.16	200	18	Seedlings	
Cactus	9	3.24	300	18	Seedlings	
Calceolaria	3	1.08	100	24	Flower forcing	
Carnations	12	4.40	400	18	Seedlings Flowering	
Chrysanthemums	15.5	5.6	500	20	Stock plants and cuttings	Can be used for long day treatment
Cyclamen	6	2.16	200	18	Seedlings	
Geraniums	6	2.16	200	18	Cuttings	
Gerbera (cut)	6	2.16	200	18	Continuous	
Gerbera (potted)	6	2.16	200	16	Seedlings	
Gloxinia	9	3.24	300	18	To flowering	
Hydrangea	18	4.4	600	24	Cutting	
Kalanchoe	6	2.16	200	18	Stock plants	Long days to prevent flowering
Lilies	9	3.24	300	18	Bud blasting	Prevents bud drop
Orchids	9	3.24	300	16	Flowering	
Poinsettias	4.5	1.62	150	18	After pinch	During periods of cloudy weather
Roses	15.5	5.6	500	18	Flowering	Winter
Snapdragons	9	3.24	300	16	Seedlings	
Stephanotis	4.5	1.62	100	18	Flowering	

*Growers with lower cost electricity may supplement with higher light intensities in some cases.

Water

The moisture requirements of plants are closely tied to light and temperature factors. Potting mediums should be well drained. Under-watering encourages salt accumulation and may lead to serious damage when plants wilt during bright, hot weather. Over-watering is a common cause of root disease. Roots are unable to obtain enough oxygen in a constantly saturated media. This leads to tissue death and provides an entry site for plant pathogens.

Watering methods should be used to provide accurate delivery of water and nutrients to the crop with a minimum of waste, leaching, and undesirable wetting of foliage. Many greenhouse potted flower producers have converted to capillary mat, trough, or ebb and flood recirculating systems. These systems offer accurate watering and great flexibility in crop configuring and spacing. They can also reduce or eliminate problems associated with run-off from greenhouses. However, subirrigation systems increase the risk of spreading soil borne diseases between plants within a production unit.

An abundant supply of good irrigation water is the first step to producing high quality greenhouse crops. Small amounts of impurities are found in almost all water sources, and while some of these may be beneficial, others can be harmful to plant growth. It is even possible for irrigation water to be too “pure”, leading to undesirable instabilities in pH. Therefore, every greenhouse fertilizer program should start with a complete irrigation water quality analysis for initial nutrient, salt, pH, and alkalinity levels.

Factors Affecting Water Quality

Ionic Content

When elemental compounds dissolve in water, they separate, or dissociate into their respective ions. Therefore, sodium bicarbonate is present in its dissolved state as sodium ions (Na^+) and bicarbonate ions (HCO_3^-). Ions having a positive charge are called cations and those having a negative charge are called anions. In any solution, the total number of anions tends to balance with the total number of cations. The actual balance between anions and cations is not the most important factor in determining the quality of an irrigation source. The relative amounts of ions in the water and which of those ions tend to predominate is more important.

Hard Water and Soft Water

Pure distilled water is said to be very soft since it contains no dissolved minerals. Likewise, rainwater and most surface water supplies are soft because they contain relatively few minerals. However, soft water does not always mean the absence of minerals. Highly mineralized water supplies where sodium is the predominant cation are also said to be soft. Soft water will produce a soap lather easily. Hard water contains high amounts of dissolved calcium and/or magnesium and does not produce a soap lather easily. Although not as desirable for washing and cleaning purposes, hard water is usually preferable to high sodium soft water when it comes to greenhouse production. Some types of water softening equipment replace the calcium and magnesium in water with sodium. This makes them unsuitable as water treatment devices for greenhouse production.

Salinity

The total amount of dissolved salts in a water supply constitutes its salinity. The cells of plant roots absorb water as a result of the difference in osmotic pressure between the cell contents and the surrounding soil water. Whenever the salinity of the soil solution is near to or greater than that of the cell contents, plants are unable to take up sufficient water for growth, cell pressure maintenance, and transpiration. Some species are more sensitive to high salts than others and mature plants can tolerate higher salts than young seedlings. Since liquid feeding programs add additional fertilizer salts to the irrigation water, it is usually desirable to start with water sources that have as low a salinity level as possible.

Non-fertilizer salts tend to accumulate in soils since they are not removed or used by the crop. Therefore, water sources with a high salinity content of non-fertilizer elements may require heavy leaching to reduce salt build-up in the growing media. This can lead to wasting of fertilizers and unacceptable levels of greenhouse run-off. High salinity water sources are less suited for use in sub-irrigated or recycled systems. When used in misting systems, highly saline water can leave a residue on plants and mineral precipitates may cause clogging of emitters.

Salinity is usually measured as a determination of the electrical conductivity (EC) of a solution. Conductivity increases with salinity. The standard unit for measuring conductivity is the millisiemen

(mS). Another commonly used unit is the millimho (mmho) which is equal to the millisiemen (mS). Sometimes salinity values are reported in microsiemens (μS) or micromhos (μmmho) when the water is very pure. One μS is $1/1000^{\text{th}}$ of a mS. Yet another commonly used unit of measurement for salinity is total dissolved salts (TDS), measured in parts per million (ppm). An EC reading of 1 mS is equal to about 666 ppm TDS.

Common Toxicity Problems

- ◆ **sodium:** high sodium levels can contribute to salinity problems, interfere with magnesium and calcium availability, and cause foliar burns associated with poor water uptake and sodium accumulation in the tissues. The sodium absorption ratio (SAR) is an indication of the sodium hazard. Most labs now report SAR adj. (adjusted), which includes a variety of other chemical factors that are taken into account to more accurately assess the sodium hazard.
- ◆ **chloride:** often associated with sodium since sodium chloride (table salt) is a common constituent of some water supplies, particularly well water. Levels above 140 ppm are considered toxic to plants. Some fertilizers also contain chlorides, such as potassium chloride.
- ◆ **fluoride:** levels above 1 ppm may cause foliar problems on sensitive crops such as lilies and freesias. Fluoride can accumulate in greenhouse media, therefore it is best to find water supplies as close to zero as possible. The small amount of fluoride that is applied to drinking water in some cities for dental health purposes does not usually pose a problem for horticulture (see the section on *Fluoride Injury* at the end of this chapter).
- ◆ **boron:** although a necessary plant nutrient, boron may sometimes be present in quantities toxic for plant growth. High boron levels are commonly associated with alkaline soil formations in areas of low rainfall.

pH

pH is a measure of the relative acidity (hydrogen ion concentration) in the water supply. It is influenced by alkalinity. The pH of the soil solution affects the relative availability of nutrients. Most greenhouse crops require a pH of about 5.5 to 6.5 in the growing medium. The pH of the irrigation source may influence medium pH depending on the buffering capacity of the medium (its ability to neutralize acids). In general, water with high alkalinity will

tend to raise medium pH. The amount of acid or base needed to change the pH of a water supply is determined by the alkalinity of the water. The purer the water the easier it is to change the pH. Water that is “too pure” may require the addition of a small amount of buffering agent, such as potassium bicarbonate, to stabilize the pH and prevent nutrient precipitation in the feeding solutions.

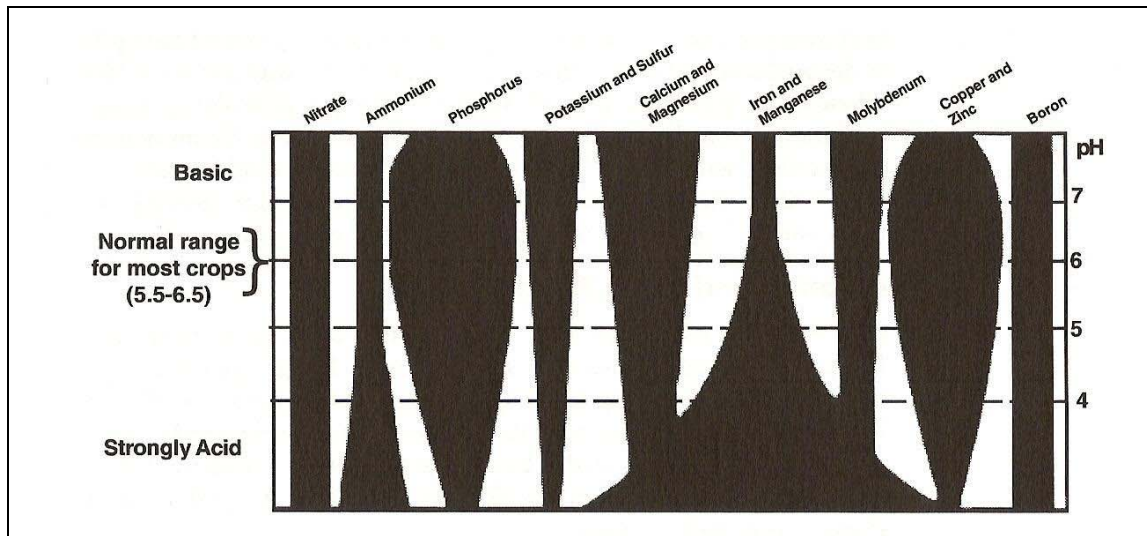
The pH of the growing media and water is one of the most important factors in production because it directly affects nutrient availability. Figure 3.1 shows that as you move from a pH of 4 to 7 the amount of calcium and magnesium available increases, while the amount of iron available decreases. This is why geraniums suffer from iron toxicity when the pH drops below 5.8.

Measuring pH is a relatively quick test that can prevent many nutritional problems. Tests should be carried out on a regular basis because many factors influence media pH. Some common factors that raise media pH include lime, alkaline water, root activity, and several nutrients (e.g. calcium, potassium and magnesium). Some factors that lower media pH include the decay of organic matter, acid forming fertilizers, and acidic water.

Alkalinity

The alkalinity of a water source is more significant than its pH because it takes into account the main constituents that affect its ability to influence media pH. An alkalinity test measures the combined amount of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), and hydroxyl (OH^-) ions. Alkalinity test values are usually reported in ppm (parts per million) or meq (mille-quivalents per litre) of calcium carbonate (CaCO_3). A pH measurement, on the other hand, only indicates the relative concentration of hydrogen ions, and provides essentially no information on how the water will affect medium pH. Alkalinity rises as the amount of dissolved carbonate and bicarbonate rises. Since bicarbonate and carbonates will neutralize acidity, and acids, in turn, will neutralize them, it is possible to correct water and media pH once the alkalinity is known. Highly alkaline water can be adjusted by adding phosphoric, sulfuric, or nitric acids. This will tend to reduce media pH over time. Similarly, overly acidic conditions can be corrected by increasing the alkalinity of the irrigation water.

Figure 3.1: How Medium pH Affects the Availability of Plant Nutrients



Plant Nutrients in Water Supplies

The presence of plant-available nutrients in the greenhouse water supply does not usually present a problem, unless they exceed the amounts normally fed to plants. However, they must be taken into account when formulating nutrient solutions. Certain fertilizer materials, such as phosphoric acid, will react at high concentrations with dissolved calcium and magnesium to form insoluble precipitates that may clog drippers. Water supplies high in calcium and magnesium may not be suited for use in mist systems due to the accumulation of unsightly mineral residues on plant surfaces.

For more information on water quality, a factsheet: [Irrigation Water Quality for BC Greenhouses](#) is available from the Ministry of Agriculture and Lands.

Planting Media

A wide range of commercial materials are available for use as planting media. Most planting mixes used today in greenhouses are soilless or contain only a small fraction of soil. Growers can either prepare their own mixes or have custom blends made for them. Whatever your preference, you should be aware that proper selection and management of your planting media is critical to the success of your crop. Some planting mixes are inert, containing essentially no available fertilizers. Other mixes may contain lime, which will supply calcium and, in the case of dolomitic lime, magnesium. Some mixes may also come pre-charged with soluble and slow release fertilizers. It is important to know the nutritional and pH status of your media before

planting, as it will affect the water and nutrient management strategy required.

Air and Water Porosity

Inadequate drainage and aeration of container media is a major limiting factor in the production of quality crops. In severe cases this may lead or contribute to the premature death of the plant. Placing a particular growing medium in a container reduces its aeration porosity due to the phenomenon of a 'perched' water table. Therefore, it is important to consider various options to increase the drainage and aeration in the container growing medium, and in doing so, promote healthy and vigorous plant growth.

Aeration and Plant Roots

Plant roots, like other plant parts, require air for the process of respiration. This essential metabolic process is fundamental to living organisms, and involves oxygen from the air reacting with stored foods within the plant cells. This releases energy for essential plant functions, such as the uptake of mineral nutrients. If the media does not supply adequate oxygen for the root system, then the plant will exhibit slow growth and will be predisposed to adverse environmental stresses.

Aeration is also necessary for the diffusion of carbon dioxide away from the roots. This gas is formed from the respiration of root cells and microorganisms, as well as from the decomposition of organic matter. The growing medium must be sufficiently porous to avoid the accumulation of carbon dioxide that would lead to the suffocation and eventual death of plant roots.

A lack of aeration caused by poor drainage leads to a wet, waterlogged, oxygen starved condition that can result in root death. The presence of dead roots predisposes the plant to attack by soil borne pathogens, such as *Phytophthora* and *Pythium*, which are responsible for root rots and damping-off.

Porosity

Aeration is a function of soil porosity. Growing media consists of solid particles, such as peat or bark, as well as the pore spaces both between and within these particles. These pore spaces are categorized into either large pores, which are normally filled with air, or smaller pores that can be either air or water filled. Although increasing aeration results in a corresponding decrease in water retention, this is the preferred situation. It is usually better to irrigate more frequently than to not have sufficient aeration. However, planting media that retains very little water will cause problems with post harvest care of potted plants. A good compromise is to use a growing medium that has sufficient large pore spaces to allow for good aeration, while still having high water holding capacity.

The best way to achieve good aeration is to select media ingredients of sufficiently large particle size. In general, there should be a good proportion of coarse textured components in the size range of 1 to 2 mm. For example, a good quality, fibrous sphagnum peat moss should be used rather than a more decomposed, less fibrous type of peat moss, like hypnum. Additional components such as perlite are often added to increase the overall air porosity.

Stability

The stability of a planting mix needs to be considered. Although sawdust initially gives a mix a high aeration porosity, its rapid decomposition may reduce the porosity over time, as well as tie up nutrients during decomposition. Peat, composted bark, and coco peat products tend to be quite stable organic amendments. Inorganic components such as perlite and vermiculite have the advantage of not being subject to decomposition, although vermiculite can lose much of its porosity through compaction.

Perched Water Table

Placing a growing medium in a container creates the phenomenon of a “perched” water table where all pore spaces at the bottom of the container are filled with water. A perched water table cannot be

corrected by increasing the number of drainage holes in the container. This is usually not a problem in a field situation, since the water table is usually relatively deep, as opposed to being almost at the surface in a shallow plug tray.

The only way to reduce the effects of a perched water table is to increase the depth of the container. For any planting mix, deep containers result in greater overall gravitational drainage and higher media air porosity. The impact of container depth on media properties is demonstrated by the data in Table 3.3. Air porosity is significantly higher in a 6 inch pot (21%) relative to a shallow plug tray (3%).

	6" Pot	4" Pot	BP Cell	Plug Tray
% Air Space	22%	15%	9%	3%
% Water Space	49%	56%	62%	68%
% Solid Material	29%	29%	29%	29%

Therefore, increasing the depth of the container will increase the drainage and aeration. In many cases economics and aesthetics preclude the use of deeper containers. But where saturated media can be a problem, such as during propagation, deeper containers should be considered. This may make particular sense with difficult to establish species where excess water is not immediately taken up by roots. The increase in aeration and the concurrent reduction in water, particularly at the surface, can also help to reduce the presence of moisture dependent pests like algae, liverworts, moss, and fungus gnats.

Improving Aeration

This can be achieved by using sufficiently coarse media components and deeper containers where feasible. In addition, growers should avoid:

- using finer components that may plug up the larger pore spaces,
- overmixing the media, which could reduce the particle size of components,
- irrigation and handling practices that may compact growing media, and
- using media components that may decompose and result in the loss of large pore spaces.

On-site Testing of Planting Media

Nutritional problems are a primary cause of economic losses associated with poor crop quality and yield. Two of the most important indicators of nutrient availability and water quality, pH and total soluble salts, are easily monitored under greenhouse conditions. With routine testing of salts and pH, and occasional complete laboratory analyses, it is possible to eliminate almost all nutritional problems associated with the production of potted and cut flowers.

pH

The pH of the growing medium and the irrigation source can affect the availability of nutrients in solution, and the health of root systems. Most plants have a relatively narrow range of preferred pH levels. The preferred range for most greenhouse crops grown in organic substrates is a pH of 5.5 to 6.5. Acid tolerant crops, such as azaleas, are usually grown at a pH of 5.0 to 5.5. Some crops are tolerant of a wide range of pH values, while others, such as geraniums require a relatively narrow range (pH 5.8 to 6.2). Although pH can be measured by chemical titration and with the use of color indicating litmus papers, an electronic pH meter provides the most accurate and practical means of on-site testing.

pH Meters

Portable pH meters suitable for greenhouse use range in price from about \$100 to \$1,000. In general, the accuracy and longevity of the meter increases with the amount paid. Most meters use a remote semi-permeable glass electrode filled with a solution of mercury or silver chloride. In some cases the electrodes are refillable, which extends their useful life. Whenever an electrode cannot be accurately calibrated between two standard buffer ranges, there is usually a problem with the electrode, or the batteries are low. These instruments must be handled and stored carefully, and the electrode end must usually be kept immersed in a liquid according to manufacturer's directions. A new type of pH meter is now available that uses a flat electrode which does not require wet storage. Other features to look for in a pH meter are automatic temperature compensation and calibration. Digital readouts are now standard in most meters. The level of accuracy needed for horticulture is to one decimal point, i.e., pH 6.2.

Electrical Conductivity (EC)

Fertilizers and other dissolved salts change the ability of a solution to conduct electricity. Pure water is not a particularly good conductor, but as the salinity level increases, its conductance also increases. Salt meters (conductivity meters) are used to measure the electrical conductivity of solutions. This provides a rough idea of the fertilizer content of the irrigation water and the media solution. One factor that must be kept in mind is that not all salts are fertilizers. Some water sources are high in nonfertilizer minerals that tend to increase the overall conductivity. So while EC measurements are a good indicator of relative fertility levels, particularly if measured regularly and tracked over time, it is important to establish the background mineral content of irrigation sources and to have an occasional complete mineral analysis performed on the media. Another point to remember is that different fertilizers have different salt indexes.

EC Meters

Portable EC meters for use in horticulture range in price from about \$120 to \$1,000. The more expensive meters should last many years, although the electrode sensors may need replacement periodically. There are a variety of inexpensive 'pen type' meters that are quite accurate and convenient to use for spot checking irrigation solutions and media salts. Standard solutions are available for calibrating the meters. Some features to look for are auto calibration, auto temperature compensation, easy to read displays, and probe replaceability. EC meters usually provide a readout in millimho's (mmho) or millisiemens (mS). They are numerically identical units. Some autoranging meters may provide a readout in micromho's (μ mho) or microsiemens (μ S). These units are 1/1000th of a millimho or millisiemen respectively.

Testing Methods

For irrigation water and fertilizer solutions, testing is a straightforward matter of monitoring the pH or EC directly. Follow the instructions provided with the meter and be careful to rinse the electrode surfaces after use and store the instruments properly. Buffered calibrating solutions are usually supplied with pH meters, and standard salt solutions are available to check and adjust the accuracy of EC meters. These calibrations should be performed often.

Water and Nutrient Solutions

Well or tap water should be checked before fertilizers are added to determine any background levels of salinity and the initial pH. It is important to allow tap water to sit for about 60 minutes when measuring pH. This allows any carbon dioxide gas dissolved in the water to come to equilibrium with the air. Dissolved CO₂ will tend to lower pH readings. If the water shows any substantial salt content (0.5 mS or above), an irrigation water quality analysis should be performed by a testing laboratory to determine the background mineral content. The report should include the elemental content, including the level of bicarbonates. Once a background EC is known, it must then be taken into account when measuring fertilizer content with a salt meter. For instance, if your water has an initial EC of 0.8 mS, then you will need to subtract this amount from your fertilizer solution readings to determine the actual fertilizer content of your nutrient solutions. This is important whenever you are checking the accuracy of injectors. Most commercial soluble fertilizers will indicate the EC values on the bag for various feeding concentrations. In order to check the calibration of your injectors, you must subtract the background EC levels from your measured fertilizer EC values after injection.

Record Keeping

Growing media should be tested for salts and pH on a routine basis. Testing should begin before the crop is planted and be performed at least every two weeks. It's important to keep records so that you can chart pH and EC levels over time. Graphically charting your pH and EC values will show whether the pH and EC are rising, falling, or staying steady. This is at least as important as the actual reading. It will enable you to make informed decisions about fertilizer concentrations, watering frequencies, and leaching rates. Growers who use routine media testing often can produce superior crops with less fertilizer and lower leaching rates, thereby reducing waste and the possibility of environmental contamination.

Collecting a Media Sample

There are two strategies available for media sampling. First, you could take several samples and measure them individually. This would provide you with a good indication of the uniformity of your watering and fertilizing program. If the results are dramatically different between pots or locations, it

might provide a clue to uneven growth or other crop problems. However, collecting and measuring 10 or more separate samples and measuring them individually can be very time consuming, and may not provide information that is any more useful than a representative or average sample. In any case, it is not practical to water and fertilize each plant individually therefore, the representative sample method is usually the one to use.

To obtain a representative sample it is necessary to combine several sub-samples to obtain an average value. Depending on the size of the crop, samples from about 10 or more pots or growing bed locations are required. Combined samples should always be from within one distinct growing unit, environment, or irrigation zone. The samples should be obtained from uniform plants that are the same type, age, and in the same size container. Try to collect your samples at the same time between irrigations, i.e., just before the next watering. Avoid sampling the top 2 cm of media since there are usually very few roots in this zone, and the salts tend to be higher due to evaporation of water from the soil surface. Salt accumulation on the surface of the media is most pronounced with subirrigation. Collect samples from the mid-range of the pot, making sure to include more than just the soil at the outside edge of the container. You can usually remove about 10% of the media without harming the plant. Fresh, moistened growing media can be used to replace the soil removed by your sample. Follow the same procedure for growing beds, by avoiding the top 2 cm and making sure that your sample is from the area of most active root growth. It is very important to be consistent in your sampling methods, so that your results will be accurate when tabulated over time. When all the sub-samples have been collected, they are placed in a clean container or bag and mixed thoroughly, taking care not to crush any controlled release fertilizer prills. The sample can then be sent in for professional analysis, or measured on-site.

Extraction Methods

Only the media solution can be tested, and there is usually not enough of it to sufficiently immerse the EC or pH probes without adding water. Also, the EC in the growing media changes with moisture content, becoming more saline as the media dries. It is therefore necessary to add enough water to the sample to immerse the electrodes and to have comparable readings from one sampling date to another.

Over the years, several dilution and extraction methods have been devised. All have advantages and disadvantages, and all may provide different instrument readings. This often leads to confusion when trying to discuss or compare values obtained from different extraction methods.

Three methods are described in the factsheet: *On-Site Testing of Growing Media and Irrigation Water* available from your nearest Ministry of Agriculture and Lands office. The factsheet details the materials, and procedures for the 1:2 extraction, the saturated media extraction (SME), and the pour-through method. Other methods such as the 1:5, and the 1:1.5 dilution methods are described briefly, although they are not as commonly used.

Air

Carbon Dioxide

CO₂ is essential for plant growth. Next to water it is the nutrient used in the greatest quantities by the plant. Plants will stop growing when the CO₂ concentration in the air drops below 180 to 200 ppm. CO₂ can be supplemented to 1,000 ppm whenever daytime ventilation is reduced. Supplemental CO₂ will have a minimal effect on plant growth under very low light conditions.

Supplemental CO₂ can be provided from pure liquid sources, or from the clean combustion of natural gas. There may be an economic advantage to supplemental CO₂ at 350 to 400 ppm during periods of ventilation since crop canopy levels can drop to 200 to 250 ppm when the greenhouse is fully vented. CO₂ burners can be placed overhead but it is often better to inject CO₂ at the crop level. CO₂ levels should be maintained with an automatic controller. Utilization of a time clock system does not provide precise control for optimum production. Some sensitive species may be damaged by CO₂ levels above 2,000 ppm. Humans should not work in levels exceeding 5,000 ppm.

Humidity Control

Adequate ventilation and air circulation can reduce the incidence of many foliar diseases. The humidity in the air is crucial to the health of plants. Humidity levels must often be reduced in greenhouses to avoid water condensation on leaves and flowers. High humidity levels can result in guttation and oedema. Guttation occurs in some species as a seepage of cellular fluids from the margins or edges

of leaves. Although guttation may not harm the plant, it can indicate a humidity problem. Oedema is a disorder brought on by wet conditions and high humidities. Cells rupture due to excessive turgor pressure (internal plant water pressure), creating calloused, corky spots on the undersides of leaves and sometimes on the stem. Ivy geraniums are especially sensitive. In addition, certain minerals such as calcium, which move only through the water conducting vessels, may not be translocated efficiently at high levels of humidity.

Humidity can be the most difficult environmental factor to control in greenhouses. Maintaining desired humidity levels can be a challenge for even the most sophisticated monitoring and control equipment. Humidity levels fluctuate with changes in air temperature, and plants are constantly adding water to the air through transpiration. Although automated controls have added a higher level of precision to the art of sensing and correcting humidity levels, it is still important to have a good understanding of the dynamics of atmospheric water vapour. There is a natural tendency with sophisticated equipment to just 'set it and forget it'. However, lost yields, plant stress, disease outbreaks, and wasted energy are still as possible as ever unless we realize the limitations of our equipment and the implications of environmental control decisions.

A factsheet, *Understanding Humidity Control in Greenhouses* is available from the Ministry of Agriculture and Lands.

Dehumidification

In greenhouses, it is usually desirable to avoid humidity levels near the dewpoint since free water condensing onto plant surfaces can promote the growth of disease organisms. Under saturated humidity conditions, plants cannot evaporate water from their leaves, so the uptake of nutrients such as calcium and boron may be limited. It is important to remember that when the relative humidity reaches 90%, it takes only a slight drop in temperature to reach the dewpoint. The problem is compounded by the fact that not all surfaces in the greenhouse are necessarily at the same temperature as the air. Any surfaces that are cooler than the air at high relative humidities will condense water vapour. This is why dripping can be such a problem with glazing materials during the heating season.

Monitoring and controlling the relative humidity of the greenhouse air is not always a guarantee that the dewpoint will be avoided. Local condensation

problems can still occur due to uneven heat distribution and the thermal mass of plant materials, particularly on plants with fruits and other large water-filled parts. This causes their surface temperatures to lag behind when sudden changes in air temperature occur. It's the same reason a glass of ice water sweats when the relative humidity of the room air is well below the dewpoint. Cold surfaces within the greenhouse cool the air immediately surrounding them. If the cooling reaches the dewpoint temperature, water condensation occurs.

Excess humidity is usually more problematic in the spring and fall seasons when the weather is cool and moist. High humidities are not as much of a problem during freezing weather, since the relative humidity of the outside air is very low. Humidity levels in the greenhouse can be reduced by venting, which exchanges moist inside air with drier outside air, and by heating. In addition to reducing relative humidity levels, heating raises the temperature of plant surfaces and warms the incoming air. Glass panes and other cold surfaces in the greenhouse serve as natural dehumidifiers when the outside air is colder. However, this may cause problems with dripping, even though the relative air humidity is low.

Preventing Condensation Problems

- Make sure your temperature and humidity sensors are accurate and located in the crop canopy. Test your temperature sensors regularly against an accurate thermometer. Bring various humidity sensors to one spot to see that they are the same. Relative humidity can also be checked with a sling psychrometer.
- Use thermal screens at night to reduce radiative heat loss from plant surfaces.
- Avoid sudden temperature elevations at sunrise by programming a gradual pre-dawn temperature rise and dehumidification period. (Sudden temperature *drops* can cause condensation problems as well, particularly on cold glazing materials as the capacity of the air to hold water decreases. However, in this case, thermal lag should prevent condensation and disease on plant surfaces, at least temporarily.)
- Place radiant heat sources near the crop to keep plant surfaces as close as possible to or slightly warmer than air temperatures.
- Use horizontal air flow fans or poly tubes to maintain even temperatures throughout the crop.
- Use a combination of venting and heating to reduce excessive humidities.

- Start dehumidifying at about 85% RH. Relative humidities above this level are not easily managed without an increased risk of condensation, disease problems, and nutrient uptake interference due to inactive plants (lack of transpiration).

Raising the Humidity

Although dehumidification is sometimes expensive, it is usually easier to reduce humidity levels than to increase them. Raising humidity levels without creating excessive free water requires some sort of evaporative device such as misters, fog units, or roof sprinklers, all of which add water vapour to the air, or screens that help hold in the water that is being evaporated from the plant canopy.

Evaporative devices accomplish three things. First, they cool the air, raising the humidity and relieving stress on the crop. Second, they add water vapour to the air, further increasing the relative humidity. Third, they reduce the vapour pressure deficit which is the force that evaporates water from the leaves. Screens may also reduce leaf temperatures and help to trap the large amount of water that the plants are evaporating. Evaporative cooling and screening are often used together. When humidifying under sunny conditions, some venting is necessary. Without venting the greenhouse would soon become a steam bath. Venting is necessary to introduce fresh, dry air that will evaporate more water and displace hot greenhouse air.

Plants, by themselves, can do an excellent job of cooling and humidifying a greenhouse. Evaporative cooling equipment works with the plants, helping relieve transpirational stress and allowing them to grow at optimum rates. The benefits of maintaining a humidification set-point include better plant quality, faster cropping, and lower disease and insect problems.

Fogs, Mists, Roof Sprinklers, and Pan & Fan Systems

Many evaporative cooling and humidifying systems are available. They add water vapour to the air, and may subsequently reduce the amount of water that the plants need to transpire. Systems should be sized to permit a maximum vapour pressure deficit of 7 grams/m³ (11 millibars) when operated in conjunction with a transpiring crop.

Roof sprinklers add water vapour and cool the incoming air. On large ranges, it is possible to decrease the temperature by 3 to 5°C and increase the humidity 5 to 10%. Pad and fan systems consist of porous wet pads at the inlet end of a fan

ventilated greenhouse. As the exhaust fans draw air through the wet pads, water evaporates to cool and humidify the air. Temperatures tend to be coolest nearer the fans and hottest at the exhaust when using these systems. Mist and fog systems produce tiny water droplets that evaporate, thereby cooling and humidifying the greenhouse air.

Points to Remember About Humidification

- Plants are the primary humidifiers/coolers of greenhouse air. Ensure adequate irrigation for evapotranspiration needs on hot days.
- Greenhouses with sealed floors tend to be drier, since evaporation from the soil is prevented.
- Heat and humidity levels are easier to manage in taller greenhouses.
- If wetting of floors or foliage occurs, stop humidifying in the late afternoon or early evening to allow enough time for drying.
- Evaporative cooling depends upon the total amount of water that can be evaporated. Evaporative cooling systems must therefore be engineered with water output needs in mind.
- Evaporative cooling requires good ventilation rates. It is the *evaporative* process that cools the air. Fresh, dry air must be continually introduced and warm, humid air exhausted.
- To measure leaf vapour pressure deficit, accurate sensors for leaf and air temperature, as well as an accurate relative humidity sensor, are required.

Plant Nutrition and Fertilization

A plant’s health and performance is dependent on the availability of the necessary macronutrients (e.g. nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur), and the micronutrients (e.g. iron, boron, manganese, zinc, copper, molybdenum, and chlorine) (Table 3.4). Some crops require more of certain elements than others. For example, poinsettias are known to require molybdenum in higher quantities than most other crops. Micronutrients, especially copper, molybdenum, and boron, can reach toxic levels fairly quickly if too much is applied.

Nutrient deficiencies often result in slow growth and poor leaf shape or colouration. Excess nitrogen produces soft leaf tissues that are more susceptible to foliar diseases such as *Botrytis*. Chrysanthemum leafminers appear to be attracted to plants grown with high nitrogen levels. Nutritional deficiencies or excesses may be avoided by checking feeding

formulas and verifying that all of the required elements are available in the correct quantities. Ensure that the correct amounts of fertilizers are incorporated into potting mixes. A soil test may be necessary. A simple test of pH and conductivity can help indicate if soil conditions are adequate. Tissue analysis can be used to determine the levels of elements actually present in a plant and to verify fertilizer imbalances.

From Air & Water	Macronutrients	Micronutrients
Oxygen* Carbon* Hydrogen*	Nitrogen Phosphorus Potassium Calcium Magnesium Sulphur	Iron Manganese Boron Copper Zinc Molybdenum Chlorine**
<p>* Oxygen, carbon, and hydrogen are assimilated from the air and water and are not normally considered under the heading of plant nutrition. All other nutrients are absorbed primarily through the root system.</p> <p>**Chlorine is required in minute quantities and is not normally applied intentionally. It is usually available in quantities far in excess of plant needs as chlorides in water supplies and in various fertilizer compounds.</p>		

Commercially prepared ‘complete feed’ fertilizers contain macro- and micronutrients. Generally the micronutrients in the mix will be sufficient to produce a good crop. Iron, especially if the media has a pH greater than 6.5, may need to be supplemented. These fertilizers often do not contain calcium, sulphur and magnesium in sufficient levels to satisfy plant needs. Therefore, premixed fertilizers may have to be supplemented with calcium nitrate and Epsom salts or magnesium nitrate unless calcium, magnesium, and sulphur are available from other sources. Dolomitic limestone in the media will also supplement calcium and magnesium levels, and gypsum (calcium sulphate) will supply calcium and sulphur. Complete feed fertilizers have been introduced that contain higher levels of calcium, magnesium, sulphur, and micronutrients, thereby reducing the need for supplements. See Appendix B, for more information on liquid fertilizers.

Tables 3.5 and 3.6 list some of the more common symptoms of plant nutrient deficiencies and toxicities. Table 3.7 shows how the availability of nutrients varies with other nutrients and with changes in pH. Use the three tables together when analyzing potential nutritional problems.

Table 3.5: Generalized Plant Nutrient Deficiency Symptoms	
Symptoms	Deficient Nutrient
Stunting of Shoot Tips	
Young leaves are thick, leathery and chlorotic; stems are brittle; “Witch’s broom” appearance; poor flowering	⇒ Boron
Young leaves chlorotic or distorted (crinkled, strap-like, downward curling of leaf tips); roots may become short, stunted and thick; weakened stems	⇒ Calcium
Wilting and dieback of shoot tips; poor pigmentation	⇒ Copper
Interveinal Chlorosis	
A. Young leaves	
Veins usually remain distinctly green; chlorosis progresses to older leaves; leaves may appear white; twig dieback	⇒ Iron
Gradation of colour from yellow to dark green at the midribs, often not a sharp distinction between yellow and green areas; leaves may develop brown or purple spots, and become necrotic	⇒ Manganese
Terminal growth stunted, forming a rosette	⇒ Zinc
B. Older leaves	
Upward curling along leaf margins; mid-rib areas remain green	⇒ Magnesium
Overall Leaf Chlorosis	
A. Occurs first on young leaves	
Associated with leaf wilting	⇒ Chlorine
Stunting and lack of vigour; distorted ‘whiptail’ leaves or leaf scorch	⇒ Molybdenum
Slow, spindly growth; leaves may turn beige	⇒ Sulphur
B. Occurs first on older leaves	
Leaves may become necrotic; stunted, slow, spindly growth	⇒ Nitrogen
Plants Dark Green with Purple Coloration of Older Leaves	
Slow growth; stunted plants; older leaves turn chlorotic, then necrotic	⇒ Phosphorus
Necrotic Spots on Margins or Tips of Older Leaves	
Weak stems and stalks that fall over easily; slow growth; small flowers	⇒ Potassium

Table 3.6: Generalized Plant Nutrient Toxicity Symptoms	
Element	Toxicity Symptoms
Ammonium Nitrogen	<ul style="list-style-type: none"> Wilted appearance of older leaves, margins of older leaves curl, may become chlorotic and eventually necrotic, root tips may burn. <i>Factors contributing to ammonium toxicity include:</i> using high ammonium based fertilizers when soil temperatures are below 15°C, low light levels, overly saturated media or when soil pH is below 5.5.
Iron	<ul style="list-style-type: none"> Chlorotic and necrotic speckling - common on geraniums and marigolds. <i>Factors contributing to iron toxicity include:</i> over feeding of iron nutrients and low pH.
Manganese	<ul style="list-style-type: none"> Chlorosis and death of the growing terminal. Some sawdusts may contain toxic levels of manganese. <i>Factors contributing to manganese toxicity include:</i> oversteaming and low pH.
Boron	<ul style="list-style-type: none"> Blackening and death of the growing terminals. Marginal chlorosis or necrosis of older leaves. <i>Factors contributing to boron toxicity include:</i> excessive amounts in irrigation water, soil or fertilizers; low pH.

Element	Excessive Amounts Inhibit	Availability as pH	
		Falls Below 5.5	Rises Above 6.5
Nitrogen	Potassium		
Ammonium	Calcium, Copper		increases
Phosphorus	Copper, Iron, Zinc, Boron	decreases	decreases
Potassium	Nitrogen, Calcium, Magnesium	decreases	
Calcium	Magnesium, Boron	decreases	increases
Magnesium	Calcium	decreases	decreases
Sulphur		decreases	
Iron	Manganese	increases	decreases
Manganese	Iron, Molybdenum	increases	decreases
Copper	Manganese, Iron, Molybdenum	increases	decreases
Boron		increases	decreases
Zinc	Manganese, Iron	increases	decreases
Molybdenum		decreases	
Sodium	Calcium, Potassium, Magnesium	increases	

Plant Nutrients

Most plants are capable of converting simple elements into more complex molecules such as sugars, starches, proteins, and lipids. Plants require carbon, hydrogen, oxygen, and several macro- and micronutrients for growth. These nutrients are described in Tables 3.8. Plants can assimilate some from the air, all the rest must be provided by either the media or the fertilizer program. Plants need nutrients in varying amounts.

Nutrient ratios are as important as the actual levels in the media. Some nutrients will interfere or promote the uptake of other nutrients. For example, the calcium:magnesium ratio should be maintained at 1:0.4 for optimum uptake of both nutrients. The ratio of some nutrients will influence the growth of the plant. For example, a nitrogen:potassium ratio of 1:1 will generally produce normal growth and height development, whereas a nitrogen:potassium ratio of 5:8 will often produce darker, shorter plants.

Another principle to consider is that plants which are active in vegetative growth will require more calcium and nitrogen, while plants that are actively flowering with little growth will require more phosphorus and potassium.

Tissue Analysis

Tissue analysis is a method to determine nutrient imbalances within a plant. The technique is an excellent diagnostic tool when used to compare

healthy and “poor” growth. Based on the results, corrective actions can be implemented. Foliar feeding can be effective as a short-term solution for micronutrient deficiencies. But it is not effective for macronutrient deficiencies, since the amount of fertilizer required to correct the deficiency is more than can be supplied.

Correct sampling is important. Before collecting a sample, contact the lab for advice on how to collect a good tissue sample. The following is a basic guide to taking plant tissue samples:

- Nutrient levels vary widely with tissue age. The general rule is to sample recently matured leaves.
- Submit a 500-gram sample of leaf tissue.
- Sometimes the damaged portion of the leaf is very small, such as with marginal necrosis. If the entire leaf was analyzed, the nutrient imbalance in the leaf margins could be masked due to nutrient levels in the rest of the leaf. In such cases, it is recommended to only collect tissue from the damaged portions of the leaf.
- Collect as little woody material as possible, since it is relatively low in nutrients and will reduce the nutrient levels detected in the sample.
- Rinse foliage in clean water if it is dirty, otherwise submit as is.
- Samples should be stored and shipped in a paper bag or box.

- Keep the sample cool and deliver to the laboratory as soon as possible. If the sample cannot be delivered immediately, air-dry the samples to avoid spoilage.

As mentioned above, it is important to submit comparative samples from healthy and affected plants.

Nutrient - Absorption Form	Role in Plant	Sources
Nitrogen - nitrate (NO_3^-), ammonium (NH_4^+), organic urea ($\text{CO}(\text{NH}_2)_2$)	used to synthesize amino acids, proteins, chlorophyll, enzymes, and nucleic acids	inorganic: ammonium nitrate, ammonium sulphate, potassium nitrate, and calcium nitrate organic: blood meal, bat guano, fish meal, and manures
Phosphorus - primary and secondary orthophosphate (H_2PO_4^- & HPO_4^-)	used in the formation of nucleic acids, enzymes, sugar phosphates, a key element in energy transfer reactions in plants, important for root system development, rapid growth, and quality of floral parts	inorganic: single and triple superphosphate, phosphoric acid, monopotassium phosphate, ammonium phosphate organic: manures, rock phosphate, guano, tankage, fish meal
Potassium - K^+ (tends to remain in ionic form in the cells and tissues)	an activator for a wide variety of chemical reactions, essential for translocation of sugars and starch formation, required for the opening and closing of the stomata by guard cells, needed for good, sturdy growth and disease resistance, balances the runaway growth effects of excess nitrogen	inorganic: potassium chloride, sulphate, and nitrate organic: greens and, manures field soils
Calcium - Ca^{++}	Important cell wall constituent, calcium pectate helps to 'glue' cells together, improves resistance to fungal and bacterial infections, important in cell division and elongation	liming materials, calcium nitrate
Magnesium - Mg^{++}	chlorophyll molecule contains magnesium, an activator for many chemical reactions and enzyme processes	dolomitic lime, magnesium sulphate, magnesium ammonium phosphate
Sulphur - $\text{SO}_4^{=}$	a constituent of amino acids, plant hormones, and certain oil compounds	sulphate fertilizers, gypsum
Iron - Fe^{++} or Fe^{+3}	a catalyst for chlorophyll formation	iron chelates, ferrous sulphate, and fritted iron (slow release)
Manganese - Mn^{++}	acts as a catalyst in oxidation reductions and is involved in chlorophyll formation	manganese chelates and manganese sulphate
Boron - BO_3^{-3}	necessary for sugar translocation, nucleic acid synthesis, and pollen formation, plants vary greatly in their requirement	borax, solubor, and sodium pentaborate
Copper - Cu^{++}	activator for several enzyme processes and may be involved in vitamin A synthesis	copper chelate and copper sulphate
Zinc - Zn^{++}	important constituent of several enzyme systems, and works as a growth regulator for several plant processes	zinc sulphate and zinc chelate
Molybdenum - $\text{MoO}_4^{=}$	essential to transform nitrate nitrogen into amino acids, legumes use Mo to fix atmospheric nitrogen, poinsettias have a higher demand	sodium molybdate, ammonium molybdate
Chlorine - Cl^-	constituent in chlorophyll, essential for photosynthesis	water supply and various fertilizers

Crop	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Azalea	1.50 - 2.50	0.20 - 0.50	0.50 - 1.50	0.50 - 1.50	0.25 - 1.00
Chrysanthemum	3.50 - 5.00	0.23 - 0.70	3.50 - 5.00	1.20 - 2.50	0.25 - 1.00
Poinsettia	4.00 - 6.00	0.30 - 0.50	1.50 - 3.50	0.70 - 2.00	0.30 - 1.00
Rose	3.00 - 5.00	0.25 - 0.50	1.50 - 3.00	1.00 - 2.00	0.25 - 0.50
Snapdragon	3.08 - 5.00	0.30 - 0.50	2.00 - 3.00		1.00 - 1.50

*From: *Agricultural Schedule of Services*, Norwest Labs, March 2003

Pollution and Chemical Injury

Pollution of soil, air, or water is an occasional cause of greenhouse and field grown plant disorders. Symptoms can sometimes be confused with those produced by plant pathogens.

Some pollutants that may cause problems are: sulphur dioxide, ozone, PANs (peroxyacetyl nitrates), carbon monoxide, and ethylene. Small amounts of ozone can be produced from metal halide and very high output (VHO) fluorescent lights. This will not be a problem unless the growing structure has a low air exchange rate and lights are placed close to the foliage. Some brown flecking from ozone may appear on tender bedding plant seedlings grown close to VHO fluorescent lights.

Fluoride Injury

Some crops, including calathea, cordyline, dracaena, freesias, gerberas, gladioli, lilies, maranta, tulips, and zebрина, are sensitive to fluorides that are sometimes found in water supplies, certain fertilizers (e.g. superphosphate), and soil aggregates (e.g. some perlites). Fluoride toxicity can be reduced if the soil pH is raised above 6.5.

Carbon Monoxide and Ethylene

Carbon monoxide (CO) injury can occur when improperly vented or operating oil or gas heaters are used. CO is odourless and is a severe health risk to humans. Ethylene damage can be associated with incomplete combustion of propane or natural gas, or an excess of senescing or ripening vegetation. Operation of gasoline engines, such as those found on some sprayers, can produce injurious levels of both carbon monoxide and ethylene in a greenhouse. Symptoms vary from burning of flowers and foliage to twisted, deformed or 'blind' growth. Ethylene damage can also occur in storage and shipping when

sensitive crops are exposed to ethylene sources, such as combustion engines and ripening fruit.

Pesticide Injury to Crops

Given the right circumstances, most pesticides can injure a plant. Greenhouse pesticides are formulated to be as safe as possible to target crops, but injury to certain varieties or species may occur.

Wherever pesticide recommendations are given in this publication, some of the more commonly damaged plants have been listed. This information is by no means complete, and growers are strongly advised to use caution when using unfamiliar materials, or familiar ones on new crops.

Spray injury can occur as marginal or complete leaf burning, leaf spots, flower spots, or distorted growth. Damage from drenched materials may also produce root death, resulting in the sudden wilting, and sometimes death of part or all of the plant.

Misuse is a frequent cause of pesticide damage to plants. Some common causes are over-application (too much chemical or too frequent), application to wet foliage (especially with fumigants), improper timing, and application to non-registered crops.

Few herbicides are labelled for flower crops. Misuse, spray drift, and residual damage from previously applied herbicides are a common cause of chemical injury (see Chapter 8).

The following precautions can minimize pesticide injury problems:

- 1. READ THE LABEL:** be sure of the proper use, application rates, and methods of applying the product. Labels often specify varieties and species that may be harmed.
- 2. CHECK THE FORMULATION:** the specific formulation of a pesticide (e.g. dust, wettable

powder, emulsifiable concentrate, etc.) can affect its safety to plants. If you use a new formulation of a familiar product, test it on a small group of plants first and monitor them for several days for signs of phytotoxicity.

3. **TIMING:** the state of plant growth is an important consideration for a pesticide application. Young seedlings and flower parts are generally more susceptible to injury than are vegetative phases of growth.
4. **PLANT ENVIRONMENT:** plants may be more susceptible to pesticide injury when under stress. This can occur when plants are under water stress. A good time to spray is often in the early morning or late afternoon. Pesticides should not be applied when temperatures exceed 25 - 30°C. Injury may also occur when pesticides are applied to wet foliage.
5. **TESTING:** before using a new material or mixture, or whenever a new pesticide is being used on a crop, it is a good idea to test it on a small number of plants. If no symptoms occur within several days, it is likely safe for crop use.

Mechanical Injury

Plants can be severely damaged through mishandling. Seedlings are particularly susceptible to injury during transplanting, so care must be taken to avoid stem and root damage.

Improper watering practices such as too much pressure, or volume, and the application of excessively cold water can be very harmful. Fans can cause damage by 'whipping' and desiccating foliage.

Plants are usually capable of recovering from some degree of mechanical injury, however, it may serve as a starting point for further problems once infections set in on damaged tissues. By using common sense in avoiding injuries, it is possible to prevent a lot of further problems and expense.