Department of Horticultural Science

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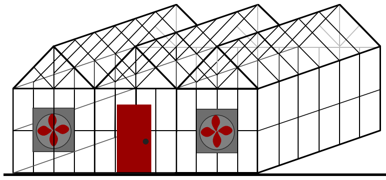

WATER CONSIDERATIONS FOR CONTAINER PRODUCTION OF PLANTS

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Water quality and quantity issues are extremely important in container production of plants. The following article addresses both quality and quantity issues for greenhouse and nursery production from a best management practices view.

Calculating Irrigation Resources and Application Efficiency

Surface water basins are the primary source of irrigation at most container nurseries. Wells are often used to recharge (dilute / freshen) and resupply water in basins. Many nurseries have always captured and recycled irrigation runoff to have adequate irrigation supplies. As environmental concern about runoff has increased in recent years this practice has increased. Growers can reduce potential problems caused by nutrients, pesticide residues and disease organisms which may be present in recycled water by allowing return water to filter through grass strips, and other vegetated areas such as secondary impoundments or constructed wetlands before allowing the water to reenter primary irrigation supplies. Aerators will help oxygenate surface waters and enhance microflora breakdown of water impurities. Many nurseries have also begun water treatment procedures such as chlorination and extensive filtration before reapplying water.

Most nursery crops grown in 1 to 5 gallon containers are irrigated with overhead impact sprinklers. A single sprinkler nozzle may require up to 15 gallons per hour for proper performance. Professionals who design irrigation systems for container nurseries suggest a minimum of one acre-inch (approximately 27,000 gallons) of water storage per acre of nursery stock per day be used in planning water supplies. Another common recommendation used for planning water supply is an estimated annual use of 5 to 10 acre-feet of irrigation water per acre of nursery stock. If container stock were irrigated for 163 days in a year at the rate of 1 acre-inch, approximately 4.5 million gallons per acre would be required annually. This is equivalent to 13 acre-feet of water per acre of nursery stock. Therefore, we recommend using 13 acre-feet of water per acre of nursery stock per year when estimating water needs.

Greenhouses also use large volumes of water for irrigation, estimated to be two quarts per square foot of covered area per day. A one-acre greenhouse uses approximately 22,000 gallons of water per day for irrigation purposes. This does not include water for evaporative cooling systems.

Water used for evaporative cooling during the summer months can dramatically increase the total water use. Under “optimum” evaporative conditions, greenhouse pad and fan cooling system water use can be as much as 0.045 gallons per 1,000 cubic feet per minute (cfm) of fan capacity. This equates to a peak demand of roughly 19 gallons per minute

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(gpm) for an acre of greenhouse. Keep in mind that evaporative rates vary drastically with temperature and relative humidity conditions. Taking into account relative humidity and temperature variances throughout the day and season, a more realistic "average" cooling water requirement would be 11 gpm for an acre of greenhouse. If pad and fan cooling is used 12 hours per day, cooling water would be about 8,000 gallons per acre per day.

An estimate of the water supply available from an irrigation basin can be made by: ❶ estimating the average width, length, and depth (in feet) of the basin; ❷ multiplying these three values to determine the approximate volume in cubic feet; and ❸ multiplying the total cubic feet by 7.5 (there are 7.5 gallons per cubic foot). If we apply $^1/_2$ inch of water per acre of nursery stock on a daily basis, we can divide the storage capacity by 13,500 gallons to determine the number of irrigation days available from the basin. This calculation doesn't take into account evaporation and all other losses of water from the basin, but is useful for planning irrigation supply.

In practice, most growers apply water to an area of containers for a specific time, such as 1 hour. The actual volume of water applied to an area is highly variable. It is dependent on: ❶ design and compatibility of nozzles used; ❷ percent of overlap between nozzles; ❸ volume and pressure drops over the length of irrigation lines and nozzles; ❹ nozzle orifice wear; and ❺ evaporative and environmental conditions such as wind. A commonly recommended volume for 1 gallon containers (7.5 inch top diameter) is 1 pint of water (0.125 gallons) with each irrigation. If 27,000 gallons of water (1 acre inch) is applied over an acre of 1 gallon container nursery stock, 0.19 gallons will enter the pot (plant canopy interference not considered). Actual volumes of irrigation applied can be determined if the nurseryman installs a water meter in the main irrigation line after the pump.

Actual measurement of the water applied is the best method of determining uniformity of irrigation. Pots with taped holes, cans or cups can be placed throughout a block of nursery stock before an irrigation cycle and collected water measured after the cycle is over. Water volume applied per container can be approximated by placing collectors with the same diameter as the containers throughout the block and catching irrigation. If the volume collected is highly variable, inspect equipment such as risers and nozzle orifices. Make sure risers are perpendicular to the ground. If nozzle orifices appear irregular in shape or larger than new orifice openings, replace them. If wind creates water distribution problems, consider creating a windbreak.

Irrigation efficiency can also be determined by removing plants from containers and observing the degree of uniform wetness in the container watered. If the irrigation was adequate, there should be no dry spots in the container root zone and water should have moved through the entire container. If irrigation continues after water has begun draining from containers, fertilizers will be leached and runoff water will have elevated levels of nutrients.

Most growers irrigate until the driest plants are watered adequately. If water is applied uniformly, less irrigation is required. Increasing efficiency is the best way to conserve water.

Water Quality Issues

Your irrigation water should be tested periodically to determine its quality. It may contain essential nutrients such as iron at high enough concentrations to justify a reduction in the levels applied in the fertilization program. Waters may also contain harmful elements or biological organisms which require corrective procedures. Table 1 lists some of the more important quality factors to consider for irrigation water for greenhouse and nursery crop use. If test results indicate levels above the recommended upper limit for a particular factor, it does not necessarily mean the water source is unacceptable, rather that some water treatment or change in production fertilization may be required.

Table 1. Recommended upper limits of nutrients and chemical capacity factors for water used for greenhouse crops and for containerized nursery crops. Use of water exceeding these suggested limits may lead to nutritional problems in sensitive crops and / or require some form of water treatment or adjustment in crop fertilization programs.

Capacity factor	Upper limit for greenhouse use	Upper limit for nursery use
	Substrate pH Factors	
pH[A]	5.4 to 7.0 is acceptable	5.4 to 7.0 is accceptable
Alkalinity[B]	2 meq/L	2 meq/L
Total Carbonates (TC as $CaCO_3$)	100 ppm	100 ppm
Bicarbonate (HCO_3^-)	122 ppm	122 ppm
Hardness[C] (Ca + Mg)	150 ppm $CaCO_3$	150 ppm $CaCO_3$
	Salinity Factors	
Electrical conductivity (EC)		
for plug production	0.75 mmho/cm	----
for general production	1.0 mmho/cm	2.0 mmho/cm
Total Dissolved Salts[D] (TDS)		
for plug production	480 ppm	---
for general production	640 ppm	1,280 ppm
Sodium absorption ratio (SAR)	4	10
Sodium (Na)	69 ppm (3 meq/L)	69 ppm (3 meq/L)
Chloride (Cl^-)	71 ppm (2 meq/L)	71 ppm (2 meq/L)
	Macro Elements	
Total Nitrogen[E] (N)	10 ppm (0.72 meq/L)	10 ppm (0.72 meq/L)
Nitrate[E] (NO_3^-)	44 ppm (0.72 meq/L)	44 ppm (0.72 meq/L)
Ammonium[E] (NH_4^+)	10 ppm (0.56 meq/L)	10 ppm (0.56 meq/L)
Phosphorus[F] (P)	1 ppm (0.03 meq/L)	1 ppm (0.03 meq/L)
Phosphate[F] ($H_2PO_4^-$)	3 ppm (0.03 meq/L)	3 ppm (0.03 meq/L)
Potassium[F] (K)	10 ppm (0.26 meq/L)	10 ppm (0.26 meq/L)
Calcium[G] (Ca)	0 to 120 ppm (0 to 6 meq/L) is normal range	0 to 120 ppm (0 to 6 meq/L) is normal range
Magnesium[G] (Mg)	0 to 24 ppm (0 to 2 meq/L) is normal range	0 to 24 ppm (0 to 2 meq/L) is normal range
Sulfur (S)	20 to 30 ppm (0.63 to 0.94 meq/L) is suggested for most plants	20 to 30 ppm (0.63 to 0.94 meq/L) is suggested for most plants
Sulfate (SO_4^{--})	60 to 90 ppm (1.26 to 1.88 meq/L) is suggested for most plants	60 to 90 ppm (1.26 to 1.88 meq/L) is suggested for most plants

[A] Water with high pH should be analyzed for alkalinity and can be safely used if alkalinity can be neutralized.

[B] Water with high levels of alkalinity can be used safely if it is treated with acid to neutralize the bicarbonates and other ions contributing to alkalinity. A limit of 1.5 meq/L alkalinity is suggested for seedling production. Labs differ in how they report alkalinity. “Alkalinity”, “TC”, and “bicarbonates” are the three main reporting methods.

[C] Hardness is a measure of Ca and Mg content, but is can be used as an indicator of alkalinity. Water with a high degree of hardness should be checked for high alkalinity and can be safely used if alkalinity can be neutralized.

[D] A conversion factor of 1 mmho/cm EC = 640 ppm TDS is assumed for TDS readings.

[E] Nitrate and ammonium provide nitrogen to plants and should not cause damage at moderate levels. Nitrate and ammonium levels higher than listed indicate that the water source may be contaminated with fertilizer or some other contaminant.

[F] Phosphorus and potassium normally occur in very low concentrations in irrigation water. If your water contains more than the listed levels, it may be contaminated with fertilizer, detergent, or some other contaminant.

[G] Acceptable limits of Ca and Mg depend upon the balance between the two. Refer to the text for further explanation.

Table 1, continued.

Capacity factor	Upper limit for greenhouse use	Upper limit for nursery use
	Micro Elements	
Aluminum (Al)	0 to 5.0 ppm is normal range	0 to 5.0 ppm is normal range
Boron (B)	0.5 ppm	0.5 ppm
Copper (Cu)	0.2 ppm	0.2 ppm
Fluoride[H] (F^-)	1.0 ppm	1.0 ppm
Iron[I] (Fe)	0.2 to 4.0 ppm	0.2 to 4.0 ppm
Manganese (Mn)	1.0 ppm	1.0 ppm
Molybdenum	---	---
Zinc (Zn)	0.3 ppm	0.3 ppm
	Organisms to Test For	
Iron fixing bacteria		
Plant pathogens		

[H] Safe for most crops but toxic for many members of the lily family (see text for complete list).

[I] Although 4 ppm is maximum for plants, even as little as 0.3 ppm can lead to iron rust stains on foliage if water is used for overhead irrigation (see text on iron fixing bacteria).

Substrate pH Factors. High water pH and high alkalinity can be limiting factors in container production of greenhouse and nursery crops. An understanding of both is needed to accurately treat water with a high pH.

A **pH** reading is a measurement of the hydrogen ion concentration of a solution (how acidic or basic a solution is), and readings range from 0 (most acidic) to 14 (most basic). Nutrient availability and future plant growth can be affected severely by high substrate and irrigation water pH (Table 2; Figure 1). Although pH 7 is considered "neutral" (not acidic or alkaline), 7 is not the optimum pH for irrigation waters or substrate solutions for nutrient availability and growth in container production due to the substrate components typically used in greenhouse and nursery production.

The recommended range of irrigation water pH and substrate solution pH for container production depends on the crop being grown. The generally accepted pH range is 5.4 to 7.0 for irrigation water and 5.2 to 6.3 for the substrate solution. Acid treatment may be needed prior to use in container production, if water pH and alkalinity are too high.

Alkalinity is a measure of a water's capacity to neutralize acids. Bicarbonate ions (HCO_3^-) from dissolved salts such as calcium bicarbonate ($Ca(HCO_3)_2$), sodium bicarbonate ($NaHCO_3$), and magnesium bicarbonate $Mg(HCO_3)_2$); and carbonate ions (CO_3^{2-}) from dissolved salts such as calcium carbonate ($CaCO_3$) are the major contributors to alkalinity in irrigation water. Hydroxide ions (OH^-) are a minor contributor in most cases. Ammonia, borates, organic bases, phosphates, and silicates can also be minor contributors to alkalinity.

Table 2. Effects of substrate pH on nutrient uptake in plants

Low pH leads to:	High pH leads to:
Increased uptake of:	Increased uptake of:
iron	molybdenum
manganese	
zinc	Decreased uptake of:
copper	iron
	manganese
Decreased uptake of:	zinc
molybdenum	copper
calcium	boron
magnesium	

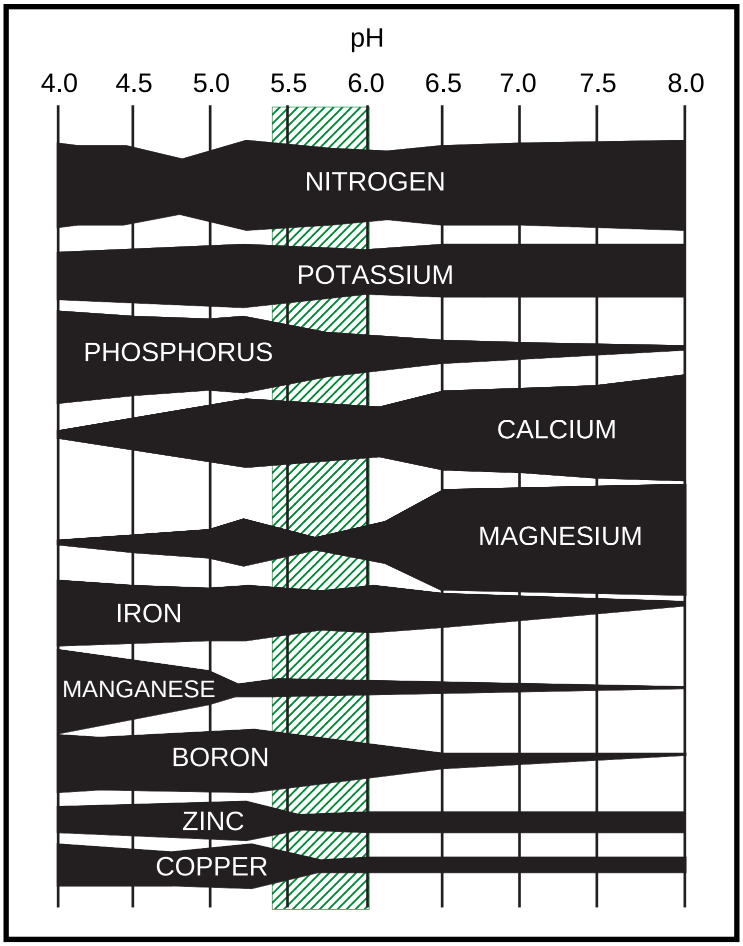

Figure 1. Influence of pH level on the availability of essential nutrients in a soilless substrate containing sphagnum peat moss, composted pine bark, vermiculite, and sand. The pH range recommended for most greenhouse crops is indicated by slashed lines.

Since bicarbonates and carbonates are the major components of water alkalinity, most laboratories assume that **Total Carbonates** (TC = carbonates + bicarbonates) equals alkalinity. In most cases, this is a safe assumption. For most waters in North Carolina, bicarbonates account for more than 90% of all alkalinity present.

The term "alkalinity" should not be confused with the term "alkaline," which describes situations where pH levels exceed 7.0. Laboratory test results sometimes express alkalinity as a calcium carbonate equivalent, using milligrams per liter (or parts per million) of calcium carbonate (mg/L or ppm $CaCO_3$). The term "total carbonates" (TC) may also be used by some testing laboratories to refer to alkalinity of a solution. The Agronomic Division Laboratories of NCDA reports alkalinity as meq/L TC. Some laboratories assume that all alkalinity is derived solely from bicarbonates (HCO_3^-) and will report alkalinity as bicarbonates using ppm (mg/L) or meq/L. To convert between these two units, use the following values: 1 meq/L HCO_3^- = 61 mg/L HCO_3^-.

Alkalinity establishes the buffering capacity of water and affects how much acid is required to change the pH. The following example may help explain the importance of alkalinity when trying to acidify water (Figure 2): Grower A has water with a pH of 9.3 and an alkalinity of 87 mg/L HCO_3^- (TC = 1.42 meq/L). To reduce the pH of this water to 5.8, it takes 15.8 fl oz. of 35% (w : w) sulfuric acid per 1,000 gallons of water. In contrast, Grower B has water with a pH of 8.3 and an alkalinity of 378 mg/L HCO_3^- (TC = 6.20 meq/L). To reduce this water to a pH of 5.8, it takes 68.6 fl oz. of 35% sulfuric acid per 1,000 gallons of water. Even though Grower B's water is one pH unit lower than Grower A's, it takes *more than four times more acid* to lower the pH to 5.8 due to the differences in alkalinity. Both alkalinity and pH are must be considered when adjusting the pH of water.

Alkalinity can be a major problem in North Carolina, especially in the coastal plain region. Levels below 2 meq/L and lower are safe for most crops. However, plug seedlings are more sensitive to alkalinity because the small volume of substrate provides little buffering against a rise in pH. Problems can occur in plug production if using water with more than 1.5 meq/L . If the alkalinity of your irrigation water is above 2.0 meq/L (or above 1.5 meq/L for a plug producer), you should consider injecting an acid to neutralize

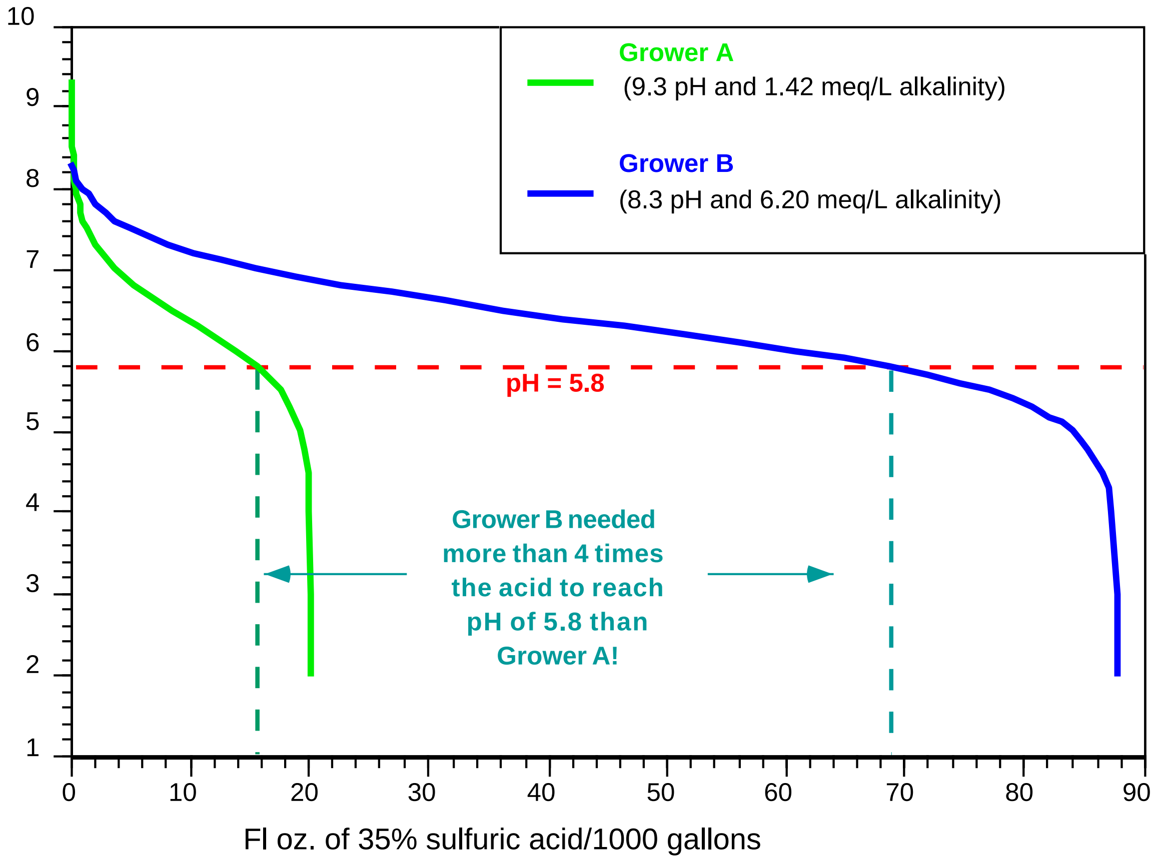

Figure 2. Titrations of two different waters with sulfuric acid. Notice that although the beginning pH of Grower A water is a full unit higher than Grower B water, it takes more than 4 times the acid to drop Grower B water to pH 5.8, due to the greater alkalinity in Grower B water.

the bicarbonates (alkalinity) present to prevent an undesirable rise of substrate pH over time.

Consideration of alkalinity naturally leads to **Hardness**. Hardness is not alkalinity! Hardness refers to the amount of calcium and magnesium in water, generally expressed as if it were all calcium and if all of it were the compound calcium carbonate ($CaCO_3$). Hardness can be expressed as mg/L or ppm of calcium carbonate.

High concentrations ("hard water") of calcium and magnesium in the water will generally be accompanied by similarly high levels of bicarbonate and a high alkalinity. That is why water hardness is sometimes used as an indirect indicator of water alkalinity. As previously mentioned, bicarbonates will cause a rise in substrate solution pH over time. Thus, it is wise to use less limestone in the substrate when high hardness water is encountered. The calcium and magnesium bicarbonates you are adding with the water are equivalent to "liquid limestone."

It is possible to have hard water without high alkalinity. An example would be water that is high in calcium and / or magnesium chloride. In this example, the problem associated with hard water is not a potential rise in pH, rather a potentially toxic level of chloride.

The take home message on water hardness is: if you have hard water, you need to look at: ❶ the alkalinity of your water; ❷ the chloride level in your water; and ❸ the Ca and Mg concentrations and the Ca : Mg ratio (discussed further with the other macro elements on page 8).

Salinity Factors. Salinity is the total quantity of salts dissolved in water, and one way to measure salinity is by measure of a water's **Electrical**

Conductivity or **EC**. A water's ability to conduct an electrical current is directly related to the concentration of dissolved salts — pure water is a relatively poor conductor of electricity, whereas salty water is a good conductor. The greater the EC, the more dissolved salts are present in solution.

Although EC is an indicator of **Total Dissolved Salts** (**TDS**), it offers no information on what salts are present and no information on the concentrations of each salt; only the total conductivity of all salts present is measured. Since individual salts conduct electricity at different rates, it is difficult to accurately convert from an EC value to a milligrams per liter value of total dissolved salts (TDS) without knowing the actual concentration of each salt present. A commonly accepted conversion factor derived from the average of many water samples is: 1 mmho/cm EC = 640 ppm TDS.

The soluble salt level, often referred to as EC (electrical conductivity), should ideally be under 0.75 millimho per centimeter (mho × 10^{-3}/cm) for seedlings, less than 1.0 mmho/cm for other greenhouse crops, and less than 2.0 mmho/cm for other nursery crops. Younger seedlings tend to be more sensitive to high salt levels than other crops, so EC monitoring is especially important for a plug grower. When a high salt level builds up in the substrate it prevents water from entering the plant roots. This results in desiccation symptoms of wilting, stunting, and burning of leaf margins.

Many growers easily become confused with different units used to report soluble salts. For example, Table 1 uses millimhos (mmho) per cm (mho × 10^{-3}/cm) as the standard units. Both the NCDA Agronomic Division Laboratories and the NCSU Plant Disease and Insect Clinic (PDIC) report soluble salts of solutions in mho × 10^{-5} per cm. It is easy to convert between the two by adjusting the decimal point (e.g. 0.75 mmho/cm = 75 mho × 10^{-5}/cm), but <u>you must pay attention to units used by different laboratories to prevent reading errors</u>. Refer to Table 3 for more conversions.

Another salinity factor beyond soluble salts is the **Sodium** concentration and the **Sodium**

Table 3. Conversions for conductivity meters and pens.

<u>Beckman Solubridge</u>

- Units are mho × 10^{-5}
- Decimal place for conversions is 10^{-5}

<u>Myron Meters</u>

- Units are millimhos/cm (mmho/cm) = milliSiemens/cm (mS/cm)
- Decimal place for conversions is 10^{-3} (mmho = mho × 10^{-3})

<u>Conductivity Pens - Several ranges of conductivity can be purchased:</u>

- Prefered range and sensitivity: 0 to 1,990 µS/cm (microSiemens) with an accuracy of ± 10 µS/cm
- Decimal place for conversions is 10^{-6} (microSiemens = Siemens × 10^{-6}); 1 Siemen/cm = 1 mho/cm
- For measuring EC of more concentrated solutions: 0 to 19,900 µS/cm ± 100 µS/cm pens are recommended
- Pens with this range are useful for measuring fertilizer solutions that have high EC values

<u>Total Dissolved Salts (TDS) Pens:</u>

- These pens read in **ppm**. Two ranges are usually sold: 10 to 1,990 or 0 to 10,000 ppm. The 10 to 1,990 ppm range is probably the better of the two. Most nutrition standards are based on EC rather than TDS, so EC pens are recommended over TDS pens. Conversions between EC and TDS range between 640 and 700 ppm TDS per mmho EC.

<u>Conversions</u>

Beckman Solubridge		Myron Meter		Conductivity Pen
20 mho × 10^{-5}/cm	=	0.2 mho × 10^{-3}/cm	=	200 mho × 10^{-6}/cm
(0.0002 mho/cm)	=	(0.2 mmho/cm)		(200 µS/cm = 200 µmho/cm)

Absorption Ratio or **SAR**. Sodium is an essential element for some plants such as celery and spinach, but most greenhouse and nursery crops have minimal sodium requirements. The SAR is a calculated value that indicates the relative concentration of sodium to that of calcium and magnesium in a water. Irrigation with waters having an SAR above 4 can result in root absorption of toxic levels of sodium, but this problem can be prevented by the addition of calcium. Water containing greater than 3 meq/L sodium should not be used for overhead irrigation of ornamentals and greenhouse plants as foliar absorption of sodium can lead to sodium toxicity in sensitive species. Sodium toxicity, whether due to root absorption or foliar absorption of Na, is expressed as marginal leaf burn on older foliage.

The final salinity factor of concern is **Chloride** concentration. Though it not usually listed as an essential micronutrient, chlorine (as chloride) is needed in small quantities by plants. However, in excess, greater than 2 meq/L, chloride can become a production problem. The principal effect of too much chloride (Cl^-) is an increase is the osmotic pressure of the substrate solution that can reduce the availability of water to plants and lead to wilting. High chloride levels can also lead to toxicity symptoms in container production. When absorbed by plant roots, the chloride ion is transported to leaves, where it accumulates. Some species, such as roses, azaleas, camellias, and rhododendrons develop leaf edge burn, leaf necrosis, and leaf abscission when too much chloride is accumulated.

Macro Elements. The macro elements **Nitrogen** (N), **Phosphorus** (P), **Potassium** (K), **Calcium** (Ca), **Magnesium** (Mg), and **Sulfur** (S) are elements essential for plant growth, and at moderate levels will not cause production problems. However, content of these elements should be evaluated as an indicator of potential contamination of the water (for N, P, and K) as well as an indicator of fertilizer requirements (for Ca, Mg, and S).

For example, nitrogen levels greater than 10 ppm are rarely found in North Carolina waters. If your water contains greater than 10 ppm N, there is a strong possibility that the water has been contaminated with a fertilizer or other contaminant. If there is greater than 1 ppm of phosphorus and / or 10 ppm potassium, the water may be contaminated with fertilizer, detergent, or some other contaminant. Although these nutrient levels should not hinder plant growth, the possibility of contamination should be further investigated, and the water should not be used for human or livestock consumption if concentrations of N, P, and K exceed the upper limits listed in Table 1.

Calcium and magnesium are normally found in North Carolina waters in the ranges given in Table 1. It is acceptable to use water containing the highest levels of Ca and Mg listed, if you reduce the amount of calcium and magnesium supplied in the fertilizer program and if the ratio of calcium to magnesium in your water source is within acceptable limits.

What is an acceptable Ca : Mg ratio in an irrigation water? The calcium and magnesium ratio in the substrate solution (and in the irrigation water) should be 3 Ca to 1 Mg if expressed as meq/L or 5 Ca to 1 Mg if expressed as ppm Ca and Mg. There is a fairly wide latitude of variance around these ratios. However, if the ratio shifts a great deal from this, a deficiency of the nutrient which is undesirably low in the ratio will occur. The more common problem is a low level of magnesium relative to calcium. In this case it is necessary to supplement occasionally with a Mg source such as magnesium sulfate (Epsom salts). Examine the ratio of calcium to magnesium (Ca : Mg) in your water to anticipate whether the substrate Ca : Mg will tend to shift out of the desired range.

Sulfur concentrations in North Carolina waters are usually less than 25 ppm, and excessive sulfur is not a normal problem. Table 1 lists recommended levels of sulfur for best plant growth. Usually, growers must add additional sulfur to reach these recommended application rates.

Micro Elements. Waters can contain small concentrations of **Aluminum**, (Al), **Boron**, (B), **Copper**, (Cu), **Fluoride**, (F^-), **Iron**, (Fe), **Manganese**, (Mn), **Molybdenum**, (Mo), and **Zinc** (Zn). With the exception of Al and F^-, these elements are essential to plant growth and are required in small quantities.

Aluminum in irrigation water is rarely found in concentrations high enough to lead to toxicities, and should not be a major concern for most growers.

Among the specific plant micronutrients found in water, boron can be particularly troublesome. A concentration of 0.5 ppm (mg/L) is safe for any irrigation use. A level greater than 0.5 ppm is above the upper limit and could lead to toxicity symptoms in boron-sensitive crops. Boron toxicity can first show up as orange-brown necrosis along the margins of older leaves. Flecking can also occur on the underside of leaves.

Other micronutrients that can be excessive in irrigation water are iron, manganese, zinc, and copper. Check levels and assure that concentrations are below the levels listed in Table 1 prior to using water. Micronutrient toxicities are more probable when the pH of the substrate solution is low, rendering the micronutrients more available for plant uptake. If the water source does contain high concentrations of these micronutrients, adjustments in the fertilization program should be made to prevent an overabundance of the elements.

Fluoride is often added to municipal water at a concentration of 1 ppm to prevent tooth decay. This level is safe for most crops but not for members of the lily family such as the genera *Chamaedorea*, *Chlorophytum*, *Ctenanthe*, *Dracaena*, *Marantha*, *Spathiphyllum* and a few other plants. Toxic levels of fluoride causes scorch of the tips of older leaves.

Harmful Organisms. **Iron Fixing Bacteria** in irrigation water can lead to many problems, including a bluish sheen on plant surfaces and brown stains on plants. The blue and brown deposits are two separate water quality problems both related to high iron content in irrigation water applied by overhead irrigation systems. The bluish bronze sheen is due to iron bacteria. They occur naturally in the soil and can be a problem in well and basin irrigation sources. In wells they often gum submersible pumps and cause them to need replacement. On basins, the oily sheen over the surface of the water is due to iron bacteria. They keep the iron in the water from settling out so when irrigation goes over plants so does the bluish iron deposit. In propagation houses you also can see a slimy yellowish mass that plugs nozzles. That is the iron bacteria.

The red-brown deposit is iron. Well water containing iron can be pumped into basins and some of the iron will settle out, but if you have iron bacteria it confounds the problem. One very important item to check is the irrigation intake. Growers have avoided or reduced the problem of iron deposits by making sure that their irrigation intakes are 18 to 30 inches below the surface of the water. They need to be at least 18 inches deep to prevent vortexing from the surface. Intakes too close to the bottom pull settled iron sediment off the bottom. Checking the location of the intake is difficult, but it is worth the effort.

If raising or adjusting the intake is not the answer, then the next choices become more expensive. The first step is to have the water analyzed at a laboratory such as NCDA (Agronomic Division N.C. Soil Testing Lab 4300 Reedy Creek Road, Raleigh, N.C. 27607; Phone 919-733-2655). Most labs need at least 16 ounces of water, so a clean plastic drink bottle sample will be fine. Water analysis at the NCDA lab costs $4.00. Although less than 0.5 ppm iron in water can stain risers and coat plants, 0.5 to 3 ppm is common in irrigation water in N.C. A foliar sample from coated plants would also be good to see how much deposit is ending up on the plants.

Employ the following methods to control iron and iron bacteria deposits: ❶ If the iron content is high enough to cause problems as indicated by the irrigation water test, the first step might be to consider a basin aeration pump. This pump just keeps the water moving and the ripples help precipitate iron and also help reduce the iron as a food source for the iron bacteria. The wave action is what adds air to the water, so a big pump creating a high fountain is not necessary. The wave action also helps keep algae and iron bacteria pushed up into coves of basins so try to locate the aeration pump where it will give the most benefit in relation to the location of the irrigation intake.

❷ The next step to consider after installing an aerifier is injection and probably filtration. Chlorine is often the material of choice as a disinfectant and oxidizing agent. Chlorine is injected into irrigation lines and usually requires some retrofitting of the irrigation system. To be effective the chlorine requires a one minute contact time in the irrigation water to kill iron bacteria or have an oxidizing effect to change Ferrous (Fe^{++}) to Ferric (Fe^{+++}). Chlorination eliminates the food source for the iron bacteria and also eliminates both types of iron deposits on surfaces irrigated. Usually storage tanks, swirl chambers or extra loops in the irrigation lines are required for adequate contact time (a minimum of 0.5 ppm for about 1 minute). Chlorination is usually accomplished by gas or liquid injection. Gas chlorination is the most efficient and effective method but is also dangerous. Liquid chlorine injection is a safer alternative. Both systems are used at nurseries in North Carolina and there are commercial irrigation contractors who can install these systems. Chlorine gas is injected from cylinders and the greatest danger occurs when cylinders have to be changed, particularly if the cylinders are housed in a building. Liquid chlorine (16 %Sodium hypochlorite) is usually purchased in 50 gallon drums and injected like other liquids but the injector usually needs to be a variable ratio injector because over time the 16% sodium hypochlorite loses strength and the injection rate must be increased.

Free chlorine is checked using a swimming pool test kit at the end of the irrigation line or riser and if the sample turns slightly, pink indicating 1 to 3 ppm, the job is getting done. The chlorine kills iron bacteria. To reduce the amount of chlorine injected, removal of organic residue is recommended, which requires filtration. Usually sand media filters are installed and two media filters generally are recommended so one can be backflushed while the other filter operates during irrigation. The cost for a chlorination and filtration system will be around $5,000.

❸ Other materials can also be injected. There are some products made for drip and micro-jet irrigation systems that contain sequestering agents, algaecides, bactericides, detergents and stabilizing agents. Filtration might not be necessary with these materials. By name, products such as Di-Solv, Aqua-Solv, and Nurserymen’s Pride (Flo Tech Automation Associates, Inc., 2151 34th Way N, Largo Fl, 34641 Phone 727.531.8796) are sold for nursery and horticultural uses. Nurserymen’s Pride was developed to clean and brighten foliage by removing dirt and chemical residues; Aqua-Solv sequesters ions in irrigation water. Like other materials, effective application depends upon equipment available and concentration of iron or other problem mineral content. Di-Solv prevents oxidation of the ferrous iron and reduces staining. Di-Solv claims that when used over time, it will clean up plants coated with iron.

Citric acid and dish washer detergent will also clean plant foliage, but for large volumes of water these products will be more expensive than other materials mentioned. An approximate rate is 1 cup of dish washer detergent (like Calgon) and 1/4 pound citric acid per 5 gallons of solution. Citric acid can be purchased from suppliers such as Worth Chemical, Durham, N.C. Phone 919.596.1386. The cost of 50 pounds of citric acid (50 pounds per 1000 gallons of cleaning solution) is about $50.00. W.A. Cleary Chemical Corporation (1049 Somerset St. Somerset N.J. 08873 Phone 201.247.8000) sells a Water Acidifier and Chelation Agent which is formulated with the dual purpose of neutralizing water alkalinity and chelating elements such as iron and magnesium, making them available for both foliar and root absorption. It is used with pesticide sprays which are more effective in slightly acid water and where alkaline waters reduce the effective half-life of a pesticide. The active ingredient of this Water Acidifier and Chelation Agent is citric acid.

Suggested Readings

Bailey, D. and T. Bilderback. 1998. Alkalinity control for irrigation water used in nurseries and greenhouses. NC State University Hort. Info. Lflt. #558. (available at www2.ncsu.edu/floriculture/)

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