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What's in your water?

First of a four-part series on monitoring irrigation water for floriculture crops

By Paul Fisher, Dustin Meador, Jinsheng Huang and William Argo

Key Points

1 Water monitoring tests and tools to measure chemical factors are available along with quality guidelines for key chemical parameters, including pH, alkalinity, electrical conductivity and the concentration of individual ions.

2 Each water source comes with its own set of challenges. Most problems can be overcome as long as the concentration of alkalinity, nutrients or waste ions in the irrigation water is within a "manageable" range.

3 Money and time spent on water quality monitoring is a form of crop insurance that will save you more expensive resources needed to fix problems.

4 Test strips are not recommended for pH and nutrient concentration measurement because of low reliability and the results can be too subjective.

A high growing substrate pH, algae on floors and clogged filters can all arise from different aspects of water "quality". High alkalinity water (a chemical factor) can cause the pH of a growing substrate to increase over time leading to iron deficiency in crops. High microbial density (a biological factor) can affect growth of biofilm in irrigation lines leading to clogged pipes and emitters. Total Suspended Solids (TSS) concentration is a physical measure of particles in the water related to the need for additional filtration. If raw water quality is treated with a technology such as copper ionization or sodium hypochlorite, the active ingredient concentration of the system should be monitored to ensure safe and effective treatment.

Chemical water quality

Most growers probably think of water quality as the chemical characteristics of water that affect nutrient management. Monitoring tests and tools to measure chemical factors are available (Table 1) along with quality guidelines (Table 2, Page 36) for key chemical parameters, including pH, alkalinity, electrical conductivity (EC), and the concentration of individual ions.

Water pH is a measure of acid (H^+) concentration in the water. As pH decreases, the concentration of acid increases. Low pH water (below 7) is therefore acidic, high pH water (above 7) is basic and a pH of 7 is neutral. A typical water pH for growing floriculture crops is in the range of 5.4 to 7.0 (mildly acidic), although a broader pH range can be successfully managed.

Impact of water pH

Water pH is important for dissolution, reactivity and efficacy of chemicals and pesticides. For example, when chlorine (from solid calcium hypochlorite, liquid sodium hypochlorite or gas chlorine) is incorporated into water, the reactions are pH dependent. At low pH, chlorine dissolves into hypochlorous acid, which is a strong sanitizer. However, at high pH there are more hypochlorite ions that are much weaker sanitizers. Therefore, chlorine is more effective at controlling pathogens below pH 7.5.

The plant growth regulator Florel (ethephon) is another chemical that is much more active at a low spray tank pH (around pH 5), whereas the PGRs daminozide and paclobutrazol are less sensitive to pH. Growers can save on chemical costs and increase efficacy by checking the pH tolerance of agrichemicals. Information sources include the pesticide label or manufacturer, or refer to the online "Indicate5 Directions and Ideal Pesticide pH Chart 2008" (www.ggspro.com/2.0/bulletins.html) from Griffin Greenhouse and Nursery Supplies Inc.

Table 1. Monitoring tools and tests for chemical water quality

Chemical factor	How to analyze	Significance	Cost	Example sources
pH (acidity or basicity)	On-site pH meter or laboratory (avoid strips*).	Fertilizer solubility (especially micronutrients such as iron), and sanitizing power of chlorine declines as pH increases.	$150 to $350 for a reliable pH meter.	Various. Hanna Instruments combo pH/EC meter, Pocket pH meters (www.specmeters.com, www.gemplers.com, www.pulseinstruments.net)
Total alkalinity ("dissolved limestone" in the water)	Laboratory, or on site colorimetric test (avoid strips)	High alkalinity (>150 ppm $CaCO_3$) increases growing substrate-pH over time, and indicates need for acid injection.	Usually included in lab water analysis. $50 to $100 for on-site kit that will do 50 to 100 tests.	Total alkalinity test kits (www.fishersci.com, www.colepalmer.com, www.hach.com).
Electrical conductivity (EC, a measure of total combined dissolved ions or "salt level", including nutrients and other ions such as Na and Cl).	On-site meter or laboratory.	Sodium, chloride, other contaminants affect plant uptake of nutrients. EC affects efficacy of some sanitizing agents (e.g. copper).	$100 to $350 for a reliable meter.	Various. Hanna combo pH/EC meter, Horiba pen EC meter (www.specmeters.com, www.gemplers.com, www.pulseinstruments.net).
Complete Nutrient Analysis identifies concentrations of individual ions (Ca, Mg, N,P,K, etc.).	Laboratory	Plant fertilizer program and toxic contaminants such as fluoride. Use to accurately measure total copper.	$25 to $100	Soil testing labs that process horticultural samples (e.g. A&L, Fafard, JR Peters, Plant and Soil Labs, QAL).

*Test strips are not recommended for pH and nutrient concentration measurement because of low reliability and the results can be too subjective.

Water alkalinity

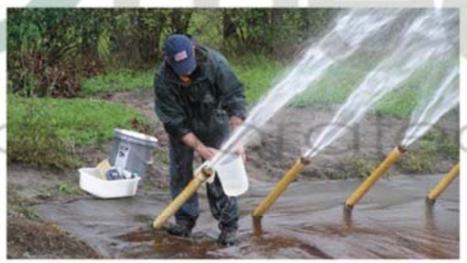
Water alkalinity differs from water pH. Alkalinity is mainly made up of carbonates and bicarbonates, and can be considered as the dissolved liming content or acid buffering capacity of water. Water that is high in alkalinity, above 150 parts per million calcium carbonate ($CaCO_3$), tends to increase the pH of the growing substrate over time because additional lime is being added from the water with each irrigation.

Often, a high substrate pH results in plant deficiencies in micronutrients such as iron. Water that has low alkalinity is more likely to lead to a low substrate pH over time. When the substrate pH is low, iron and manganese toxicity may result from excessive solubility and uptake of those elements by plants.

Typical alkalinity concentrations in floriculture production range from between 0 (for rain or reverse osmosis water) to 6 milliequivalents (0 to 300 ppm of calcium carbonate equivalents). The "ideal" alkalinity concentration depends on many factors including the type of fertilizer used, as well as how frequently clear water is applied to a crop.

High alkalinity can be reduced with the addition of a strong mineral acid such as sulfuric acid. See the North Carolina State University website Alkalinity Calculator (www.ces.ncsu.edu/depts/hort/floriculture/software/alk.html) to calculate acid rates. High alkalinity can also be counteracted by increasing the ammoniacal nitrogen concentration (acidity) of the fertilizer.

Low alkalinity can lead to low pH problems (micronutrient toxicity), but can be better managed by selecting less acidic (low ammoniacal nitrogen, high nitrate nitrogen) fertilizers.



Collecting water samples for analysis.

Photo by Paul Fisher

Electrical conductivity

Water electrical conductivity is a measure of total concentration of soluble salts. Irrigation water with a low electrical conductivity (0.0 to 0.5 milliSiemens per centimeter) is advantageous, because soluble salts are less likely to accumulate in the growing substrate. Irrigating with

Table 2. Guidelines for manageable ion levels contained in water.

Values given in parts per million (mg/L) unless otherwise noted. A "manageable" range in this table indicates that crop health can be acceptable with proper adjustment of the ions in the water using acid or chemical fertilizers, leaching, or other management changes.

CHEMICAL FACTOR	SYMBOL	MANAGEABLE RANGE	COMMENTS
pH		4.5 to 9.0	Water pH can affect the solubility of some fertilizer salts and the efficacy of insecticides, fungicides and plant growth regulators. In general, the higher the pH, the lower the chemical solubility. However, high water pH, in itself, is not a good indicator to what other ions are in the solution or how the irrigation water will affect growing substrate pH or nutrition management. The closer water pH is to 4.5, the lower the alkalinity level. At a water pH of 4.5, the alkalinity concentration is 0, and small additions of acid can drop pH to hazardous levels for plants and people. Although rare, irrigation water with a naturally-occurring pH of less than 4.5 is an indication of the presence of an acid source and should only be used with extreme care.
Alkalinity	Calcium carbonate equivalents (CCE)	< 300 ppm calcium carbonate ($CaCO_3$)	Most growers aim for an alkalinity in the range of 0 to 150 ppm $CaCO_3$, but the desired alkalinity concentration can be higher if fertilizers with higher levels of ammoniacal nitrogen (more acidic) are used. High alkalinity can be reduced with injection of a strong mineral acid such as sulfuric acid.
Electrical conductivity (EC)		< 0.75 mS/cm < 1.5 mS/cm	Maximum level for plugs and propagation. Maximum level for irrigating potted crops.
Calcium	Ca	< 150 ppm	High levels of calcium are not particularly detrimental to plant growth, except that they may be an indication of high salt levels in the water or a lack of balance with magnesium. Low levels of calcium in the water can be supplemented with the addition of calcium nitrate-based fertilizers.
Magnesium	Mg	< 75 ppm	High magnesium levels are rare, and as long as they are in the proper ratio with calcium, are not a problem. However, high levels of magnesium can be an indication of high salt levels in the water. Low magnesium levels in the water can be supplemented or the proper balance with calcium obtained with the addition of magnesium-based fertilizers.
Sulfur	S	< 120 ppm	High sulfur levels in raw water occasionally occur. However, sulfuric acid is frequently used for alkalinity control, and, therefore, in areas of the country with high alkalinity, high sulfur levels are common. Adding high levels of sulfur to irrigation water will increase water electrical conductivity, and may interfere with calcium uptake under certain situations.
Iron	Fe	< 2.0 ppm	Except for iron, it is uncommon to find high levels of micronutrients in irrigation water. If high levels of a specific micronutrient are present, then the irrigation water may have to be considered a source of that micronutrient, and the water-soluble fertilizer program should be adjusted accordingly. Aeration, treatments such as chlorine, ozone or potassium permanganate that oxidize water, followed by settling and/or filtration, can effectively remove these ions from the water.
Manganese	Mn	< 0.5 ppm	
Zinc	Zn	< 0.5 ppm	
Copper	Cu	< 1.0 ppm	

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low-electrical conductivity water usually does not require leaching during crop production because problem ions such as sodium and chloride are not likely to be at high concentrations when water electrical conductivity is low. Reduced leaching results in less water use and minimizes fertilizer runoff.

Plant species vary in their tolerance of high electrical conductivity water (greater than 1.5 mS/cm). If the salts from the water are allowed to build up in the substrate, then plant growth is often stunted. Plants may wilt even when the substrate is moist.

High electrical conductivity can cause marginal leaf burn especially in sensitive crops such as heliotrope, New Guinea impatiens, pentas and ferns. High water electrical conductivity levels can be managed by treating with reverse osmosis to remove some or all of the salts, blending the high electrical conductivity sources with a water source with lower electrical conductivity (such as captured rain water) or through periodic leaching of the growing substrate.

A moderate electrical conductivity (above 0.5 mS/cm) is desirable when ionizing copper for water sanitation, because pure water does not conduct the electricity needed to convert solid copper into dissolved ions. When water electrical conductivity is low, copper ionization can follow after inline injection of water soluble fertilizer, or copper surface area and contact time can be increased.

Nutrient, ion concentrations

The concentration of the individual nutrients nitrogen(N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), and molybdenum (Mo) in the water should also be checked, along with ions that are not essential nutrients, such as sodium (Na), chloride (Cl), aluminum (Al), and fluoride (F). When irrigating with water-soluble fertilizers (termed fertigation), the nutrient solution is a blend of ions in the water plus the ions added from the injected fertilizers and/or acid. Therefore, although low concentrations in the irrigation water of some nutrients can be beneficial, high concentrations of one or more nutrients may require adjustments in a fertilizer program.

Several other issues can occur when individual ions are excessively high. For example, high concentrations of calcium and iron can be antagonistic to plant uptake of magnesium and manganese, respectively. Water that is high in calcium and magnesium is known as hard water. Most plant species are tolerant of high calcium and magnesium concentrations (i.e., combined concentrations exceeding 150 ppm). However, overhead irrigation with hard water can leave unsightly white salt deposits on the foliage, especially with mist propagation.

High micronutrient concentrations (particularly boron) can be phytotoxic. High iron concentrations in the water can lead to staining of foliage and growth of bacteria that clog irrigation lines. Significant concentrations of sodium and chloride increase

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Table 2 continued from page 36 Guidelines for manageable ion levels contained in water.

CHEMICAL FACTOR	SYMBOL	MANAGEABLE RANGE	COMMENTS
Boron	B	< 0.5 ppm	It is uncommon to find high levels of boron in irrigation water. Boron can occasionally be at a high enough level to force changes in the fertilizer boron concentrations. For example, if boron were present in the irrigation water at 0.5 ppm, then it could probably be eliminated from the water-soluble fertilizer. Boron is not effectively removed with reverse osmosis purification. To compensate for extremely high boron levels in irrigation water (>1.0 ppm), the general recommendation is to keep the substrate pH above 6.0 and use calcium-based fertilizers, or find a new water source.
Sodium	Na	< 50 ppm	Sodium and chloride are waste ions and their presence in irrigation water can be an indication of high salt levels. High sodium levels can also be an indication of low calcium and magnesium levels, and high boron levels in the water. High sodium levels can cause a degradation in substrate-physical properties over time, particularly in substrate containing field soil.
Chloride	Cl	< 70 ppm	
Total chlorine	HOCl & OCl-	< 2.0 ppm	Chlorine (not chloride) can produce phytotoxicity on sensitive plants at concentrations at 2.5 ppm or above.
Fluoride	F	< 1.0 ppm	Fluoride is added to many municipal water sources. Fluoride can be removed from water with activated carbon filters or sensitive crops can be protected by keeping the growing substrate pH above 6.0 and using calcium-based fertilizers.

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the water electrical conductivity and can disrupt nutrient uptake, without contributing to plant growth. Ions such as aluminum and fluoride are not essential plant nutrients but can be toxic to plant growth above threshold concentrations.

Measuring ions

Measurement of individual ions generally requires laboratory analysis. Refer to the laboratory report to interpret high or low values. If you use Table 2 as a guide, consider that a "manageable range" is broader than a "target" range. There is no perfect irrigation water for crop production.

Each water source comes with its own set of challenges. Most problems can be overcome as long as the concentration of alkalinity, nutrients or waste ions in the irrigation water is within the "manageable" range in Table 2. This manageable range can be achieved either through proper management of alkalinity or by supplementing or balancing the nutrients contained in the water with those supplied by acid or chemical fertilizers.

Inexpensive crop insurance

Money and time spent on water quality monitoring is a form of crop insurance that will save you more expensive resources needed to fix problems. Regular monitoring of chemical water quality does not need to be expensive, with a complete water test one to four times a year (depending on whether your water quality tends to change between seasons), in combination with in-house testing of pH and electrical conductivity.

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The laboratories and instruments mentioned are intended as examples of resources, not an endorsement of specific suppliers or brands. GM

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