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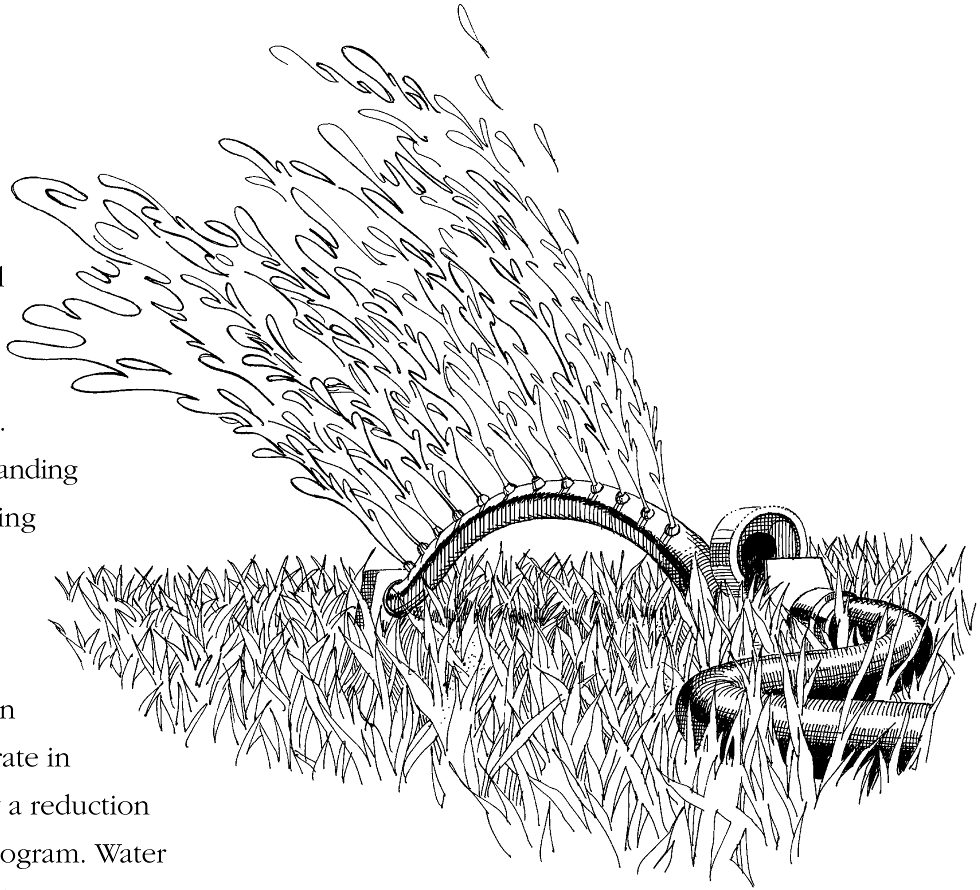
ANR-1158

Water Quality Management for Greenhouse Production



A dependable irrigation water supply is a vital component of any greenhouse growing operation. In the past, the quality of the water source was not a cultural issue considered by growers. They did, however, incur fertility problems that often defied explanation. Over the past 10 years, a better understanding of how water quality can impact potting media pH, soluble salts, fertility, and plant growth has made water quality a critical issue in greenhouse crop culture. The water source may contain essential nutrients such as iron or nitrate in high enough concentrations to justify a reduction in levels applied through a fertility program. Water may also contain harmful impurities that require corrective procedures.

Water quality can be a deciding factor when choosing among sites for establishing a new greenhouse business or, where the opportunity exists, to choose among two or more water sources at a particular site. Growers should have their irrigation water tested by a university or private laboratory any time a new water source is established, whether it be from a well, river, pond, or municipal system. Afterward, test the water at least twice per year or often enough to establish how much variability there is in water quality over time. One good approach is to take one test during a wet period and another during a dry period because high rainfall can dilute water impurities and drought can concentrate water impurities. Once a water quality pattern has been established, yearly testing is usually sufficient. The cost is generally $15 to $25 per sample.

Water Quality Factors

A water sample should reflect the properties of the water source before coming into the greenhouse facility. Collect the water sample as close to the sources as possible (e.g., well head or main inlet). Allow the water to run long enough to flush the line, about five minutes. Then collect at least 1 pint of water in a new polyethylene or polypropylene plastic container or a boron-free glass container. Avoid containers with metal lids or containers washed with phosphate-containing detergents. Fill the container completely with water, allowing no air space, and seal the lid tightly. Promptly send the sample(s) to an appropriate laboratory.

pH

Water pH is a measure of the hydrogen ion (H^+) concentration on a scale of 0 (most acid) to 14 (most basic) with 7 considered neutral. Potting medium solution pH can have a large effect on both the availability and form of fertilizer nutrients for plant growth. However, it is a misconception that irrigation water pH controls potting medium pH. The main effect of irrigation water on potting medium pH is from water alkalinity. However, a high water pH (7.2 or higher) should be a warning that the alkalinity of the water needs to be tested. An acceptable pH range for irrigation water is in Table 1.

Alkalinity

Alkalinity is a measure of the irrigation water's ability to neutralize acid in the potting medium solution and can, therefore, raise the pH over time. Alkalinity relates to pH because it establishes the buffering capacity of the water. Alkalinity is composed of dissolved bicarbonates (HCO_3^-) from calcium, magnesium, or sodium bicarbonate and carbonates ($CO_3^=$) from calcium or magnesium carbonate in the water. Dissolved bicarbonates and carbonates in irrigation water neutralize hydrogen ions in the potting medium solution and raise the pH.

Alkalinity is measured by slowly adding a standard solution of sulfuric acid to a water sample of known volume to achieve a pH of 4.5. The amount of acid required is directly proportional to the alkalinity. Most laboratories report alkalinity as parts per million (ppm or mg/L) of calcium carbonate or as milliequivalents per liter of calcium carbonate (meq/L). Some laboratories test for bicarbonates and carbonates then report the sum of the two as alkalinity (total carbonates). Other labs report bicarbonate alone as alkalinity. This is often a safe assumption because 90 percent of alkalinity is often composed of bicarbonate. Upper recommended limits for alkalinity and bicarbonate in irrigation water are in Table 1. However, these upper limits depend on the length of the crop period, potting media volume and buffer capacity, and the upper pH level tolerated by a crop species.

For example, seedlings grown in plug flats are more sensitive to high water alkalinity because the

Table 1. Recommended Upper Limits of Chemical Factors in Irrigation Water for Greenhouse Crop Production[1]

pH		5.4 to 6.8
Alkalinity		150 ppm $CaCO_3$ (3 meq/L)
	Bicarbonates	122 ppm (2 meq/L)
	Hardness (Ca +Mg)	150 ppm $CaCO_3$ (3 meq/L)
Electrical Conductivity		
	plug-grown seedlings	0.75 mmhos/cm
	general production	1.5 mmhos/cm
Total Dissolved Salts		
plug-grown seedlings	480 ppm	
	general production	960 ppm
Sodium Absorption ratio		4 (no unit)
Sodium (Na)		69 ppm (3 meq/L)
Chloride (Cl^-)		71 ppm (2 meq/L)
Nitrogen (N)		10 ppm (0.72 meq/L)
	Nitrate (NO_3^-)	10 ppm (0.16 meq/L)
	Ammonium (NH_4^-)	10 ppm (0.56 meq/L)
Phosphorus (P)		1 ppm (0.3 meq/L)
	Phosphate ($H_2PO_4^-$)	1 ppm (0.01 meq/L)
Potassium (K)		10 ppm (0.26 meq/L)
Calcium (Ca)		120 ppm (6 meq/L)
Magnesium (Mg)		24 ppm (2 meq/L)
Sulfur (S)		20-30 ppm (0.63-0.94 meq/L)
	Sulfate (SO_4^-)	30-45 ppm (0.63-0.94 meq/L)
Iron (Fe)		0.2-4.0 ppm
Manganese (Mn)		1.0 ppm
Boron (B)		0.5 ppm
Copper (Cu)		0.2 ppm
Zinc (Zn)		0.3 ppm
Fluoride (F^-)		1.0 ppm
Aluminum (Al)		5.0 ppm

[1] Adapted from D. Baily, T. Bilderback and D. Bir. 1996. Water considerations for container production of plants. North Carolina State University Horticulture Information Leaflet 557.

small potting medium volume offers little buffer to a rise in pH. Problems can occur in plug production at higher than 75 ppm alkalinity. Likewise, pH can rise in the potting medium over time in long-term crops as repeated applications of high alkalinity water accumulate bicarbonates. Finally, crops that grow best at a low potting medium pH will be less tolerant of high water alkalinity.

Hardness

Water hardness is a measure of the amount of calcium and magnesium dissolved in the water expressed as if it were calcium carbonate. Even though water hardness is not the same as alkalinity, hard water is often accompanied by high alkalinity. It is possible, however, to have hard water without high alkalinity such as when calcium or magnesium chloride are present as impurities in the water. The upper recommended limit for water hardness in irrigation water is in Table 1.

When water hardness is greater than 150 ppm, it is important to check the amount of calcium and magnesium dissolved in the water and determine the Ca : Mg ratio. This ratio should be 3 to 5 ppm calcium to 1 ppm magnesium. If there is more calcium than this ratio, it can block the ability of the plant to take up magnesium, causing a magnesium deficiency. Conversely, if the ratio is less than 3-5 Ca : 1 Mg, the high proportion of magnesium can block the uptake of calcium, causing a calcium deficiency.

Soluble Salts

Soluble salts refers to the concentration of total salts (electrically charged ions) dissolved in the irrigation water. It is measured by using an electrical conductivity meter. The water's ability to conduct electricity is directly related to the concentration of total dissolved salts. The unit for electrical conductivity (EC) is the mmhos/cm, which is the reciprocal of the ohm, a unit of electrical resistance. EC may also be reported in dS/m, which is equal to mmhos/cm.

Irrigation water high in soluble salts transfers the salt to the potting medium and can accumulate over time. Fertilizer, fungicidal drenches, and breakdown of organic media components can also contribute additional salts. High soluble salts in the potting medium competes with the roots of plants and may inhibit uptake of water and nutrients or, in extreme cases, physically damage roots. As noted in Table 1, young seedlings are generally more sensitive to high soluble salts than older plants are.

Other Salinity Factors

Total dissolved salts refers to the concentration of all salts in the water expressed as parts per million. It is calculated from EC. However, because EC does not measure what individual salts are present and individual salts conduct electricity differently, it is difficult to accurately convert mmhos/cm to parts per million. A commonly accepted conversion is 1 mmhos/cm = 640 ppm. The upper recommended limits for total dissolved salts in irrigation water are in Table 1.

More specific indicators of salts present in irrigation water are the sodium absorption ratio (SAR) and measurements of sodium and chloride. SAR is a calculated value that indicates the relative concentration of sodium to calcium and magnesium in the water. It reflects that the presence of calcium and magnesium counteracts high levels of sodium. SAR greater than four can result in root uptake of toxic levels of sodium.

Irrigation water high in sodium and/or chloride usually occurs along coastal areas where saline water intrudes into the water supply. High sodium and chloride can damage plants through phytotoxic action of the two ions and interference in root uptake of water and nutrients. The upper recommended limits for sodium and chloride in irrigation water are in Table 1.

Plant Macronutrients

Nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur are essential plant nutrients and at moderate levels in irrigation water should not cause production problems. However, water content of these nutrients should be evaluated as indicators of potential contamination from other sources. If the level of any of these nutrients exceeds the values in Table 1, greenhouse fertility programs should be reduced accordingly to prevent overapplication of a nutrient.

Plant Micronutrients

Iron, manganese, boron, copper, and zinc are essential plant micronutrients that can be excessive in irrigation water. Check the concentration of these nutrients to assure that they are below the levels indicated in Table 1. Micronutrient toxicities are more likely when the water and potting medium pH is low, making the nutrients more available for plant uptake. Avoid additional micronutrients in the fertility program if the water source also contains high concentrations of these nutrients.

Fluoride is often added to municipal water supplies at 1 ppm to prevent tooth decay in humans. This level is safe for most greenhouse crops except members of the lily family including the genera *Chamaedorea, Chlorophytum, Ctenanthe, Dracaena, Marantha, Spathiphyllum,* and a few others. Toxic concentrations of fluoride cause tip scorch on older leaves.

Aluminum in concentrations high enough to cause production problems is rarely found in irrigation water, and should not be a major concern for greenhouse growers. The upper recommended limits for fluoride and aluminum in irrigation water are in Table 1.

Water Treatment

High Alkalinity

Several methods can be used to correct high alkalinity in the water supply depending on the severity of the problem. As noted above, acceptable alkalinity ranges can depend on potting media volume as follows: plug-grown seedlings, 60-100 ppm; small pots, 80-120 ppm; 4- to 5-inch pots, 100-140 ppm; pots greater than 6-inch, 120-180 ppm.

Water alkalinity up to about 40 percent higher than the upper range of these values can be corrected by reducing the amount of limestone added to the potting medium and/or selecting acidic-reaction fertilizers. Most greenhouse potting media requires limestone to raise the pH within a range acceptable for plant growth. Applying water with moderately high alkalinity can be viewed as applying liquid lime. Therefore, incorporating less limestone at the time of mixing the medium can be used to compensate for alkaline water. The amount of limestone to add to the medium is that amount that achieves the minimum potting medium pH required by the crop at the start, but does not result in a high pH at the end of the crop. Exact rates of limestone are difficult to provide and must be determined by trial and error. Start with one-half the usual rate. Frequent testing of the medium pH is essential to determine the correct limestone rate.

Moderately high water alkalinity can also be corrected using acidic-reaction fertilizers in the greenhouse fertility program. The label on a fertilizer container reports the pH reaction of the fertilizer in pounds of potential acidity or basicity per ton.

Table 2. Characteristics of acids used to neutralize water alkalinity.[1]

Acid type	Concentration	Nutrient content (ppm)	Neutralizing power
Phosphoric	75% (food grade)	25.6 phosphate	45[2]
Sulfuric	93%	43.6 suflate	136
Sulfuric	35% (battery)	16.4 sulfate	51.2
Nitric	63%	14.6 nitrate	52.3

[1] Adapted from R. Vetanovetz and S.O. Ferry. Adjusting alkalinity with acids. Ohio Florists' Association Bulletin, May 1997 Number 811.

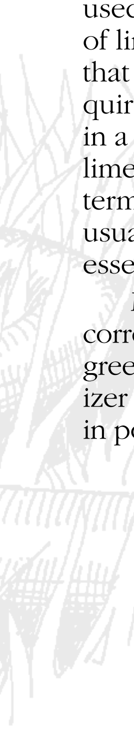
[2] Alkalinity neutralized (ppm CaCO3) with 1 fluid ounce per 100 gallons of water.

Applying a high potential acidity fertilizer will neutralize alkalinity in the water and prevent a rise in medium pH during the crop. Common acidic fertilizers are 20-20-20 (474 lbs/ton potential acidity) or 20-10-20 (422 lbs/ton potential acidity), although a very acidic fertilizer is a 20-2-20 (800 lbs/ton potential acidity).

When the water alkalinity is very high, it becomes necessary to take stronger action by injecting acid into the water supply to neutralize bicarbonates. This action should only be taken when reducing limestone in the medium and using acidic-reaction fertilizers have proven inadequate. Three types of liquid acids have commonly been used to neutralize alkalinity in irrigation water. Nitric acid is available in concentrations of 67 percent and 75 percent, and sulfuric acid is available in a concentration of 93 percent. All of these are dangerous to handle and can be damaging to fertilizer injectors and pipes, but are used in greenhouses. Phosphoric acid is available in concentrations of 75 percent and 85 percent, is much safer to handle, and is more commonly used. Sulfuric acid is also available in a 35 percent concentration (battery acid) that can be purchased at automotive supply companies. It is inexpensive and relatively safe to handle.

Acids can be delivered into the water supply using acid-compatible injectors. Check with the injector manufacturer to be sure the unit can handle the chosen acid. Acid should be delivered through an injection head separate from fertilizer or use a separate injector unit.

The amount of acid to inject in the water supply can be determined one of two ways. An alkalinity calculator is available through North Carolina



State University on the World Wide Web at http://www.ces.ncsu.edu/depts/hort/floriculture/software/alk.html. Table 2 also provides the amount of alkalinity neutralized by several acids at 1 fluid ounce per 100 gallons of water. Determine the current alkalinity level from a water test and subtract the desired alkalinity to get the amount of alkalinity to neutralize with acid. Then use the data in Table 2 to determine how much acid to inject.

Keep in mind that injecting nitric, phosphoric, or sulfuric acids into the water supply also adds essential plant nutrients that must be subtracted for the normal fertilizer program to prevent overapplication of these nutrients. In particular, injecting more than 2.25 fluid ounces per 100 gallons of phosphoric acid can increase the amount of potting medium phosphorus to unacceptable levels.

Acids are hazardous chemicals so always wear the proper safety equipment including safety glasses, face shield, rubberized apron or coveralls, and acid-resistant gloves and boots. Use acid-resistant containers for acid stock solutions. Always add acid to water slowly, stirring it into the water.

Low Alkalinity

Ironically, low alkalinity water can be a concern for greenhouse growers. Water sources with low pH and low alkalinity can decrease the potting medium pH over time, especially where acid-reaction fertilizers are used. The chances of micronutrient toxicities can increase as the potting medium pH decreases, especially in geranium, marigold, and New Guinea impatiens. One way to correct low water alkalinity is to increase the amount of limestone mixed with the potting medium. The amount of limestone to add to the medium is the amount that achieves the maximum potting medium pH tolerated by the crop at the start, but does not result in a low pH at the end of the crop. Exact rates of limestone are difficult to provide and must be determined by trial and error.

Low water alkalinity can also be corrected using low acid- or basic-reaction fertilizers in the greenhouse fertility program. Common basic-reaction fertilizers are 15-0-15 (319 lbs/ton potential basicity), 14-0-14 (229 lbs/ton potential basicity), or 13-2-13 (200 lbs/ton potential basicity). It also helps to reduce the amount of micronutrients used in the fertility program.

Reverse Osmosis

Reverse osmosis is a purification process where water is forced through a plastic film porous to water but not to impurities. This treatment procedure removes microorganisms, alkalinity, salinity, and other dissolved ions. However, the equipment and special films are very expensive and as much as 20 percent to 50 percent of the intake water is discarded. Therefore, the cost of reverse osmosis can only be justified when water quality is poor, crop value is high, and alternative water sources are unavailable.

Water Softening

Softening water is a process of replacing calcium and magnesium in hard water with sodium. Alkalinity and other ions still remain in the water. Therefore, softening water is not recommended unless followed by reverse osmosis treatment.

Summary

Choosing the best water treatment program for a greenhouse operation should follow a process of testing the water source to identify what problems exist, choosing a treatment method that is economical and effective, and frequent water and potting media testing to determine if the water treatment yields the desired result. The time spent in obtaining information and proper follow-through can more than pay for itself in improved crop quality.

Additional Reading

Paul V. Nelson. 1998. Greenhouse operation and management. Prentice-Hall, Inc., Upper Saddle River, NJ, ISBN: 0-13-374687-9.

David Wm. Reed. 1996. Water, media and nutrition for greenhouse crops. Ball Publishing, Batavia, IL, ISBN: 1-883052-12-2.

Thomas C. Weiler and Marty Sailus. 1996. Water and nutrient management for greenhouses. Northeast Regional Agricultural Engineering Service, Ithaca, NY, NRAES-56.

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ANR-1158

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