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Understanding Irrigation Water Test Results and Their Implications on Nursery and Greenhouse Crop Management

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Water quality can have a huge impact on plant growth, especially in soilless plant production systems. Water is certainly one of the most critical inputs in nursery and greenhouse crop production. Such production systems are extremely diverse but are most commonly characterized as container production, raised-bed production or hydroponics. Soilless systems require intensive management of water and nutrients for optimal plant growth and production. Irrigation water quality impacts nutrient levels and availability as well as other chemical characteristics of the soilless growth substrate; therefore it is critical to characterize the irrigation water source before starting a crop and possibly even during the production of a crop, depending upon the cropping cycle and expected fluctuations in water source. The purpose of this fact sheet is to discuss irrigation water quality factors and to present general guidelines for optimal ranges for measured factors in a University of Kentucky water analysis for nursery and greenhouse crop production.

Water Testing

Water testing services are available through the Kentucky Cooperative Extension Service as well as private laboratories. In general, the state services are less expensive but may be limited in the number of factors tested. Kentucky growers can submit water samples through the local county Extension office for analysis by the UK Soil Laboratory in the College of Agriculture for a modest fee. The decision of which service to use will depend on the production system and water source. A standard test that measures the most critical water quality factors is acceptable for most plants, including bedding plants, potted flowering crops, hanging baskets, trees and shrubs. More rigorous testing is advisable for hydroponic systems and young plant (plug, liner or transplant) production. Water tests can also be used to confirm the content of

nutrient solutions for fertigation or hydroponics. Pesticide build-up can be an issue in production systems capturing runoff from large blocks of plants. Testing for most pesticides requires sending samples to specialized, commercial labs which have the necessary equipment and protocols. Regardless of the laboratory service used, the sample collection protocols are generally the same. Water testing should be repeated on a regular basis as the quality of water from the same source will vary over time. For example, drought can reduce the volume of stored water, which may result in an increased concentration of minerals. As water evaporates, the minerals left behind will be in a smaller volume of water.

To submit a sample to UK, first obtain a sample submission form and bottle from your county Extension office. Collect the sample from the water source (tap or spigot for municipal water sources) rather than the irrigation system because residues in the irrigation system could skew the test readings. It is also a good idea to let the water run briefly before collecting the sample. Leave a half-inch air space at the top of the sample bottle. Replace the bottle cap tightly. Mark the sample with the owner identification and return the sample and completed submission form to the Extension office. If samples must be held, store them in a refrigerator, but do not freeze. The more information provided on the submission form about the crops to be grown, any past or current undesirable crop symptoms, etc., will result in more targeted comments and recommendations. A report from the UK Soil Laboratory will be sent electronically to the county Extension office that submitted the solution sample to the lab. The report will contain the results of the analyses and information from the submission form. The county agent will provide the report and comments, with assistance from an Extension specialist as appropriate, to the grower submitting the sample.

Water Quality Factors

Water quality factors include physical, chemical and biological properties. Physical properties include suspended solids such as soil particles. The presence of solids in the irrigation water can easily clog low-volume irrigation emitters and even robust sprinkler heads. Filtering a water sample using filter paper or finely woven cloth can indicate the presence of suspended particles in the water.

Biological properties of interest include the presence of iron fixing bacteria, plant pathogens or algae. Iron fixing bacteria can grow in irrigation systems and clog emitters but are usually associated with excessive iron levels in the water. Plant pathogens, such as water molds, can become an issue in irrigation water, especially if the irrigation water is recycled. Recycled irrigation water can be in a closed system such as hydroponics or more open systems such as holding ponds positioned to capture irrigation runoff plus rainfall. Algae are most common in slow moving streams or ponds. Biological properties are not included in routine water tests as they are relatively expensive but the expense may be warranted for evaluation of a new water source or to assist in diagnosing the cause of crop plant abnormalities. These tests must be conducted at a commercial water testing laboratory and are not included in a routine water test like the one available at the University of Kentucky.

Chemical properties of irrigation water are the properties most often tested because they can cause significant production issues, and the information gained from the test can be used immediately in crop management strategies. Only chemical properties are included in the UK water test analysis. A description of the chemical properties routinely included in these water analyses is provided below.

pH is the measure of the relative concentration of hydroxide ion (OH^-) and hydrogen ion (H^+) present in the water. pH is measured on a scale of 1 to 14 with 7 being neutral. Distilled or de-ionized water has a pH of 7. A pH below 7 is considered acidic, and a pH greater than 7 is basic or alkaline (not to be confused with alkalinity). The pH of irrigation water is a concern but must be considered in the context of the alkalinity of the water. It is a common misconception that the pH of the water will determine the pH of the growth substrate. In most cases, the alkalinity (buffering capacity) of the irrigation water has more effect on the substrate pH than the pH of the water. However, high pH can be indicative of high alkalinity, so if irrigation water is found to be greater than 7, the alkalinity should be tested. High pH in conjunction with high alkalinity can cause serious issues for crops in soilless growing systems.

Alkalinity is the measure of the water's ability to neutralize acids, including those found in fertilizers and growing substrates. Water that is high in alkalinity will neutralize acid, causing the pH of substrates to rise over time or in some cases very quickly. Alkalinity is composed of dissolved calcium, magnesium or sodium bicarbonates and calcium or magnesium carbonates. These dissolved carbonate and bicarbonate ions neutralize hydrogen ions, which increases the pH of the substrate solution. Most laboratories report alkalinity in ppm (parts per million) or meq/L (milliequivalents of calcium carbonate per liter of water). The UK Soil Testing Laboratory expresses alkalinity in ppm. The recommended upper limit for alkalinity in irrigation water varies depending on the buffering capacity and volume of the substrate, the crop time and the pH sensitivity of the crop. The larger the substrate volume the more buffering capacity is present so the pH will change much more gradually in large containers than small containers or individual cells in a plug tray.

Plug production is very sensitive to high alkalinity as the very small volume of substrate in the plug has little buffering capacity, allowing the pH to change rapidly. The same is true in hydroponic systems as the substrate is usually inert, offering almost no buffering capacity. In these systems, problems can occur with an alkalinity as low as 50 to 75 ppm. For production of plants in 4-inch or larger containers that are not particularly pH sensitive, an alkalinity value of up to 150 ppm is manageable. Managing high alkalinity will be discussed in the "Water Treatments" section.

Electrical Conductivity is used to measure of the total dissolved salts (free ions) in the water. Soluble salts are detected by measuring the electrical conductivity of the irrigation water since it is the dissolved ions that conduct the electrical current through the water. Pure, distilled water does not conduct electricity. Electrical conductivity (EC) is usually reported as mmho/cm, which is the reciprocal of the ohm, a unit of electrical resistance, and the scientific standard for measuring EC. The metric equivalent for the mho is Siemens ($1 \text{ mmho/cm} = 1 \text{ mS/cm} = 1 \text{ dS/m}$). The level of soluble salts that is acceptable in irrigation water varies from near zero for hydroponic systems up to about 1 mS/cm for potted crops. Higher conductivity means more salts in the water, which can lead to plant injury under certain conditions.

Plant macronutrients are present in irrigation water in highly variable quantities so irrigation water tests also measure the presence of these plant essential nutrients. This information allows growers to determine if some elements can be reduced or even removed from the fertility

regime in the event that they are already present in the irrigation water in sufficient quantity. Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) generally do not negatively impact plant production if present in irrigation water in moderate quantities. The presence of nitrogen or phosphorous in substantial quantities will not harm plants but can be indicative of a contaminated water source. In such cases additional testing should be done to determine if pathogens are present. If less than 60 ppm calcium and 25 ppm magnesium are detected, supplementation will be necessary for most crops. Many “complete” fertilizer formulations for greenhouse and nursery crops do not contain sufficient calcium and magnesium as water sources may contribute significant amounts.

In addition to the measured content of these ions in the irrigation water, the relative concentration between ions can be important as well. For example, “hardness” is a measure of dissolved minerals, usually calcium and magnesium ions, in the water. These ions are typically associated with carbonate ions. So while hardness and alkalinity are not the same, they are frequently linked. However, the calcium and magnesium ions in the water may be present as calcium or magnesium chloride, causing hardness with no contribution to alkalinity. Hard water, i.e. high levels of calcium and/or magnesium, can also result in the accumulation of sediments that can clog irrigation systems. For water with high alkalinity or hardness, it is important to also consider the ratio of calcium to magnesium ions. The ratio should be 3 to 5 calcium : 1 magnesium. A high proportion of magnesium ions can block calcium absorption leading to calcium deficiency. Also, the “sodium absorption ratio” (SAR) is another factor that must be considered in cases where high sodium levels are present in the irrigation water. SAR is calculated from the relative concentration of sodium to calcium and magnesium. High levels of calcium and magnesium can counteract the negative effects of the presence of sodium. A SAR value of 4 or greater can cause plant roots to uptake damaging amounts of sodium. This is usually only an issue in coastal areas where salt water incursions may enter the groundwater. Also, home water softeners function by replacing the hardness (calcium and magnesium ions) with sodium ions, so water that has passed through a softener should never be used for irrigation.

Plant micronutrients zinc (Zn), copper (Cu), iron (Fe), manganese (Mn) and boron (B) levels are reported by most irrigation water tests as these can be present in excessive quantities in some cases. Micronutrient toxicities are more common when substrate pH is low, which increases the availability of most of these nutrients. Also

if the irrigation water does not contain micronutrients they will need to be provided through the fertility program. Most municipal water sources will contain some fluoride, which is added to drinking water to prevent tooth decay. The levels added to municipal drinking water are usually not high enough to cause problems for most crops. However, a few crops are highly sensitive to fluoride toxicity such as *Spathiphyllum* (peace lily), *Dracaena*, *Chamaedorea* (parlor palm), *Chlorophytum* (spider plant), *Ctenanthe Marantha* (prayer plant) and a few others.

General Interpretation of Water Test Results

General recommendations are provided here with the realization that production systems, crops and environments differ significantly in the nursery and greenhouse industry. More precise recommendations for unique crops or cropping systems are required in some instances. Such recommendations can be obtained through your county Extension office and the UK Department of Horticulture.

pH

- 5.5 to 7.0—generally acceptable
- Less than 5.5—potential problem, and the elemental constituents of the water should be examined closely
- Greater than 7.0—a possible problem, especially if there is high alkalinity; may interfere with the effectiveness of some pesticides and growth regulators when used as spray water

CONDUCTIVITY (*measure of soluble salts*)

- Less than 0.75 mS/cm—no problem expected
- 0.75 to 3.0 mS/cm—increasing concern of excessive accumulation of soluble salts over time
- Greater than 3.0 mS/cm—expect severe problems

ALKALINITY

- Less than 150 ppm—no problem expected; 100 ppm is high for plug production
- 150 to 300 ppm—increasing concern if the water pH is greater than 7.5. Expect the pH of the growing substrate to increase throughout production of the crop; use acidifying fertilizers regularly, and use a more acid growing substrate.
- Greater than 300 ppm—significant problems if the water pH is greater than 7.5. The substrate pH will rise rapidly throughout the production of the crop and cause many nutrient problems. Acid injection into the water may be the only remedy if this water source must be used for irrigation.

NITRATE–NITROGEN

- Less than 5 ppm—no problem expected
- Greater than 5 ppm—no cultural problems for plant production; however, a nitrate level greater than 5 is a good indication that your water source is polluted. There can be greater variability in this laboratory measurement compared to other measurements.

PHOSPHORUS

- 0 to 3 ppm—no problem expected
- Greater than 5 ppm—could interfere with the uptake of other nutrients; addition of P in the fertilization program may not be necessary; could be signal of potential water source contamination by applied fertilizer, detergents, etc.

POTASSIUM

- 0 to 10 ppm—no problem expected
- Greater than 10 ppm—no cultural problems for plant production expected. Potassium levels this high in Kentucky water samples are rare and could be potential sign that the water source is contaminated with fertilizer.

CALCIUM

- Less than 60 ppm—expect calcium deficiencies in plant production unless calcium is added in the fertilizer program.
- Greater than 60 ppm—no cultural problems for plant production expected. Hydroponic nutrient solutions for plant production use rates of 80 to 130 ppm Ca. Irrigation water with high calcium may need no additional Ca additions through fertilization. Higher amounts of Ca will compete with P and Mg and reduce their availability to plants.

MAGNESIUM

- Less than 25 ppm—expect Mg deficiencies in plant production unless magnesium is added in the fertilization program.
- 25 to 50 ppm—should be adequate for production of most plants; hydroponic nutrient solutions use rates of 30 to 50 ppm Mg
- Greater than 50 ppm—no cultural problems for plant production. Irrigation water with high Mg may need no additional Mg additions through fertilization. Mg levels this high in Kentucky water samples are rare and could be a sign that the potential water source is contaminated with fertilizer.

ZINC

- 0 to 0.3 ppm—no problem expected
- Greater than 0.3 ppm—could cause toxicity in sensitive plants, especially at low substrate pH; high Zn in Kentucky water sources is rare and could be a sign that the potential water source is contaminated from old galvanized pipe.

COPPER

- 0 to 0.2 ppm—no problem expected
- Greater than 0.2 ppm—could cause toxicity in sensitive plants, especially at low substrate pH; high Cu levels in Kentucky water sources are rare

IRON

- 0 to 1 ppm—no problem expected
- Greater than 1 ppm—could cause foliar spotting in sensitive plants and clog some micro-irrigation emitters
- Greater than 5 ppm—can cause toxicity symptoms in some plants, particularly at a substrate pH below 5.5

MANGANESE

- 0 to 1 ppm—no problem expected
- 1 to 2 ppm—usually not toxic to plants and usually not found this high in Kentucky water sources

BORON

- Less than 1.0 ppm—no problem expected. However, poinsettia is particularly sensitive to boron toxicity from B levels as low as 0.5 ppm.
- 1.0 to 2.0 ppm—toxicity may be a problem on some plants
- Greater than 2.0 ppm—expect toxicity symptoms at low substrate pH

SODIUM

- Less than 50 ppm—no problem expected
- Greater than 50 ppm—expect salt concentration in the growing substrate to increase over time

Management Strategies

Water quality factors outside the acceptable range do not necessarily mean that the water source cannot be used. There are water treatment options available to growers that can correct many water quality problems. However, some may require expensive equipment and materials to function, so often the best solution is to find an alternate water source. It is advisable for growers to investigate several water sources and evaluate the relative cost of utilizing them to determine if it will be economical to treat water from a less expensive source such as a well,

stream or pond or pay more for municipal water, which in almost all cases is acceptable for greenhouse and nursery irrigation. The most common water quality problem in Kentucky is high alkalinity, so it will be discussed in more detail here.

Management of Alkalinity

Fertilizer selection is one method to manage pH in soilless production systems when using irrigation water with moderate alkalinity. Every fertilizer is labeled with a potential acidity or basicity value in CCE (calcium carbonate equivalents; lbs/ton). A fertilizer formulation with a high potential acidity can balance the effects of moderately high alkalinity, keeping the substrate pH within an acceptable range. This is especially true in systems where soluble fertilizers are added frequently during irrigation. If this method is used, regular sampling of substrate pH is *imperative*. Common nursery and greenhouse fertilizers have been carefully formulated and their expected impact on pH is known and documented.

In simple terms, “Potential Acidity” or “Potential Basicity” as listed on the fertilizer package refers to the effect that this fertilizer product has on substrate pH. The higher the number for potential acidity, the more acidity the fertilizer provides. Potential basicity works the same way. For example, Peters Peat-Lite Special has a moderate acidity potential but their 21-7-7 Acid Special has more than three times the acidification potential.

Acid injection will likely be necessary if alkalinity is excessively high (300 ppm or more) to make the water suitable for irrigation in soilless production systems. There are several types of acid that are used to neutralize excess alkalinity in irrigation water. No matter which type is used, *safe handling of concentrated acids is a serious concern*. When mixing any acid, proper safety gear must be worn, including safety glasses, face shield, and acid resistant apron, gloves and boots. Also, all employees that will be working around the system should be aware of the nature of these materials and what precautions are warranted. When acid injection is necessary it is advisable to invest in an alkalinity test kit to allow monitoring alkalinity on a regular basis to ensure the system is running properly.

The acid must always be added to the water. Never add water to concentrated acid as an energetic reaction will occur that may cause the acid to splash. When mixing an acid solution, measure carefully to ensure accuracy and use acid-resistant materials. Always stir the solution after the acid is added, as acids are heavier than water and will sink to the bottom of the tank, leading to inconsistent injection concentration.

The most commonly used acids are phosphoric, nitric, sulfuric and citric. The choice of which acid to use depends upon the amount of acidification needed, as well as the relative cost and safety of the material. For moderate alkalinity levels, many growers opt for phosphoric acid, as it adds phosphorus to the final fertilizer solution and is safer and inexpensive than most other acids. For extremely high alkalinity, sulfuric (or battery) acid has the highest neutralizing ability but is more hazardous to handle. Citric acid is relatively weaker and less expensive but is the safest to handle and may be approved for use in some organic production systems.

Once the acid has been chosen, the next steps are selecting the right injector and calculating the amount of acid needed in the stock solution. Read the specifications before purchasing an injector for use with acid. The manufacturer will state the maximum concentration of acid that the device can withstand.

There are many factors contributing to the actual alkalinity change that will occur, so *conducting a test or calibration run of the acid injection system is a must*. For more information on calibrating acid injection, please refer to a University of Florida publication on the subject at <http://edis.ifas.ufl.edu/ss165>.

Remove Solid Particles

Water filtration is an option for removing solid particles and unwanted minerals. Simple mechanical filtration can remove some minerals and particulates from the water. A filter system utilizing sand, cellulose or ceramic sieves is advised when any surface water source will be used. This step will reduce irrigation system clogging by particulate matter and algae. More advanced and costly filtration systems such as reverse osmosis are necessary in cases where the water quality problems are very serious. Reverse osmosis removes nearly all alkalinity and impurities from the water and can render almost any water source usable for greenhouse production; however these systems are expensive to install and operate so identifying an alternative water source is always advised if such extreme water treatment is deemed necessary.

Control of Biological Factors

Sterilization of irrigation water is necessary in cases of contamination with iron fixing bacteria (usually associated with excessive iron levels), plant pathogens or algae. Also in systems that recirculate water such as ebb and flood systems, plant pathogens and algae can accumulate in the water. Regardless of the source of pathogen contamination, a system of sterilizing the water prior to use or re-use may be necessary in closed systems. Tradition-

ally, growers have used chlorine injection to rid water of biological contaminants. While this system is effective, the grower must maintain a delicate balance between correcting the problem and allowing chlorine levels to negatively affect the plant. Also a separate injection system is needed for chlorine injection. Other options available to growers include copper ionization systems and ultraviolet light (UV) sterilizers, which kill plant pathogens without adding a chemical sterilizing agent to the water. These systems are used to treat swimming pool and fishpond water as well, so suppliers of these products may have more knowledge and selection of UV and copper sterilization systems. These systems are relatively expensive, so it is advisable to consider the cost of alternative water sources in an economic analysis.

Routine Water Sampling Improves Management

The modest cost of a basic water test is a small price to pay to insure the water source is suitable for the crop and production system under consideration. Regular water testing can help avoid lost production and costly repairs to irrigation systems. Keep all water sample reports and make notes as to any production protocol adjustments in response to each report. Records of routine water sampling results can reveal changes over time and help anticipate seasonal differences.

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