How To Test & Evaluate Water Quality

ÆssenseGrows

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WP02

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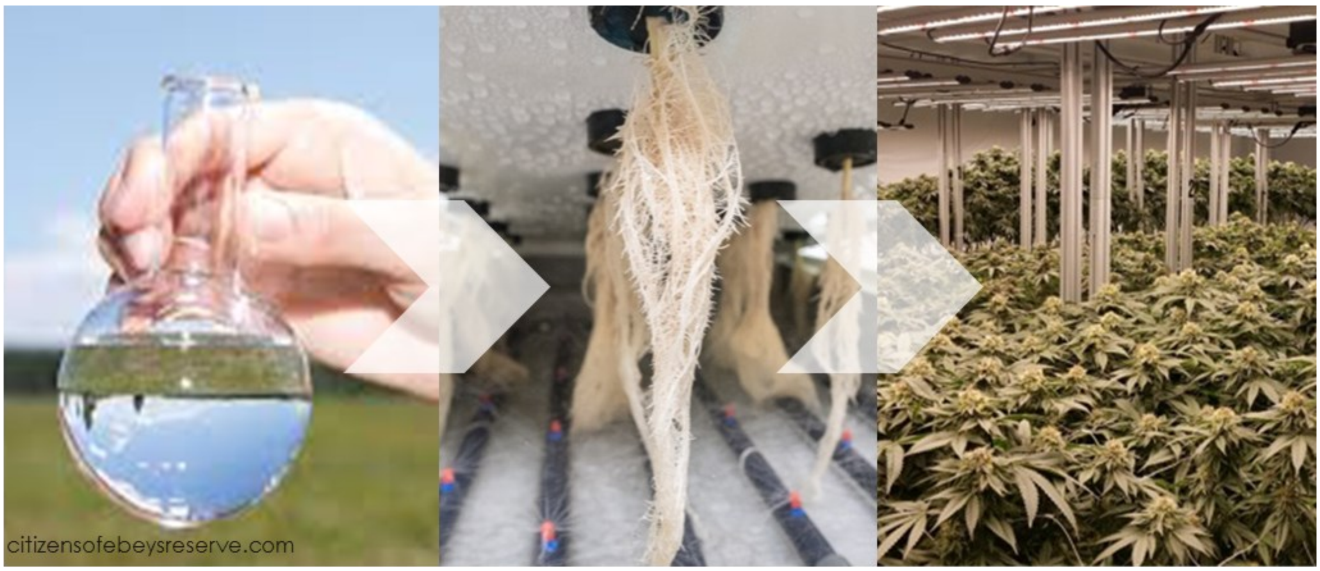
Introduction

Understanding water quality is an essential step in providing the optimal growing conditions for plant production. Water is considered to be the universal solvent because more substances dissolve in water than any other liquid. Unfortunately, not all of the components in the source water are beneficial, in fact some may be deleterious to healthy plant production.

Whether investigating a new production site or maintaining an existing facility it is important to look into the various aspects of water quality. The makeup of the water as well as your expectations will influence management decisions related to the necessity to pretreat the water for irrigation, cultural practices related to methods of irrigation, and design of fertility program. These decisions and practices will all influence plant production, management practices, and associated costs.



Source Water

All of the management decisions regarding water and irrigation begin with the water source. Identifying and fully understanding the source of water is a critical first step in the due diligence process of site identification.

Since water is such an essential component in plant growth, this is not something that should be overlooked or underestimated. It is important to know what the quality, quantity, and output of your source water is. These characteristics are important to understand not just to determine the suitability of a particular property, but also to ensure proper maintenance and operations of an existing nursery, greenhouse, or production facility.

Depending upon the location and intended use of the property and facility, water will come from one of three sources: municipal, groundwater (well), or surface water.

Municipal

In urban areas, municipal water is often the only available source of water. One of the primary benefits of municipal water is that it is generally considered to be consistent regarding quantity and output, meaning that the flow rate and availability are relatively predictable and reliable.

Municipal water sources all go through some degree of pre-treatment to ensure potability (suitability for human consumption) depending upon the originating source of water. Additionally, municipal water treatment facilities also add compounds to the pretreated water for residual water sanitation (chlorine) or for potential health benefits (fluoride). Though these elements may benefit human consumption, they may create challenges for plant production. Variability and inconsistencies in quality may exist in municipal water supplies as they often blend multiple sources of water to meet demand. Despite these inconsistencies, municipal water sources do provide comprehensive water quality reports free of charge. Though these reports may not reflect current output, they will provide an indication to whether additional treatment is required for use as a suitable irrigation water.

The greatest challenges of municipal water as a source for agricultural use is the cost. In 2015, residents of San Francisco paid, on average, $250 per month for a family of four consuming 100 gallons of water per person daily (fig. 1). Municipal water is often too expensive for large fields, it may be a suitable option for high value crops and small areas.

Fig. 1: 2015 average monthly water cost of 30 major U.S. cities for a family of four consuming 100 gallons of water per day per person (www.circleofblue.com)

Groundwater

Groundwater is a common source of water in rural or non-urban areas and for agricultural use. Groundwater is subsurface water that occurs below the water table within the pore spaces of geologic formations, and is accessed and supplied by drilled wells. These subsurface aquifers become saturated by precipitation and store and transmit water in usable quantities (CAWSI).

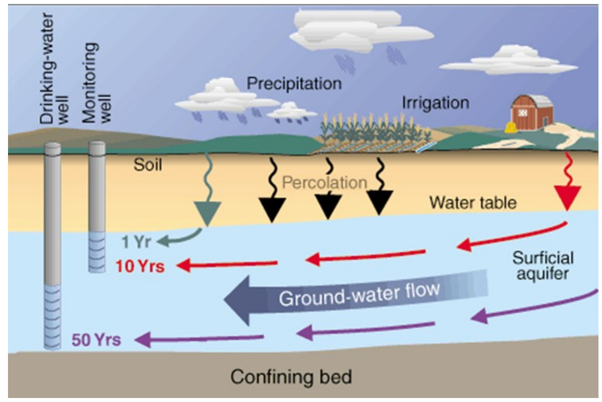


Fig. 2: Chemical lag time to appear in groundwater
USGS Water Science School

Because groundwater reserves are recharged through precipitation events infiltrating through the soil profile, chemical contaminants can be present in the water (fig. 2). Shallow wells are often more susceptible to contamination from surface sources, but overall quality of the water in a well is influenced by land use activities, environmental conditions, and subsurface geologic features. For instance, in coastal regions, groundwater may have impurities such as sodium chloride or sodium bicarbonate, whereas regions of limestone deposits may have excessive levels of calcium bicarbonate. These impurities could impact plant growth and subsequent management decisions.

Groundwater sources will also vary in accessible depths depending upon location of the aquifer. The depth of groundwater as well as adjacent water use will influence the depth of the well and the initial cost of establishment. When investigating new sites without a preexisting well, well history (including quality and output) may be available for adjacent properties to provide an estimate on water potential. Contact your local Extension office, water board, or DNRC for more information on obtaining this information.

Surface Water

Fig. 3: Siphon tubes from a surface water ditch.
www.wikiwand.com

Surface water is generally the least expensive source of water for irrigation, but is also the least dependable. Surface water sources include natural features such as rivers, streams, and lakes; and man-made features such as farm ponds, ditches, and canals (fig. 3).

Surface water sources are not only dependent upon runoff from adjacent land and upstream features, but from upstream use. Therefore, quantity of water from surface sources can vary especially on a seasonal basis. Since surface water sources are charged from a wide range of sources and geographic area, largely from runoff, the quality can also vary. Surface water is subject to many sediment, biological, and chemical contaminants which will influence quality for irrigation and potability.

The Food Safety and Modernization Act (FSMA) has recently established guidelines for use and testing of surface water sources when in contact with consumable agricultural products. Good Agricultural Practices (GAP) and Good Handling Practices (GHP) are more frequently demanded by wholesale and retail marketplaces further requiring safe and clean water for production and postharvest management. It is important to understand if these rules, exemptions, and management requirements that may be necessary for compliance.

Surface water sources also require water rights, so it is important to not assume that if water exists on the property that access is automatic. Contact your local Extension office, water board, or DNRC for more information to determine water rights.

How To Determine Water Quality?

To ensure consistent and uniform results in plant production, it is essential to understand the quality of your water. It is not only important to know the quality of the source water in order to make management decisions regarding necessity for pretreatment or suitability, but it is also essential to monitor the irrigation water to ensure quality upon delivery through irrigation.

Water quality can be determined through simple in-house testing practices as well as comprehensive analysis from analytical laboratories. Regardless of testing procedure, in order for the test results to be of value, they must represent the quality of water in use or the water that is considered for use. Furthermore, proper testing procedures, analysis, and record keeping are essential. Without reliable data and interpretation of your irrigation water quality, you may have unpredictable growing results.

Fig. 5: Handheld digital sensor. www.bluelab.com

In-House Capabilities

In-house water testing is an inexpensive option that provides instantaneous results providing a viable solution to monitor in-use water quality. Available tools and associated costs limit the extent to what can be monitored. Most often, growers are monitoring electrical conductivity (EC) and pH using handheld sensors (fig. 5), and colorimetric kits are available for approximating mineral content. The actual impact of EC and pH on plant growth will be addressed in a later section.

Fig. 6: AEssense AEtrium water sensors

Colorimetric kits can be purchased at most garden centers and allow growers to gain a ballpark value of specific nutrient content (typically macronutrients like nitrogen, phosphorous, and potassium) by adding a reagent to the solution and matching the resulting color with a provided table. These can be a useful tool to approximate levels as these tests are relatively inexpensive, but since they do not give precise values and are somewhat subjective based on the user's interpretation, they are therefore not necessarily reliable for verification of precise values.

In-line sensors allow for remote monitoring, data logging, and real-time response. The AEssense AEtrium systems have sensors (fig. 6) in place to monitor EC, pH, and water temperature providing continuous in-use monitoring without the need for handheld sensors (fig. 7).

Calibration and maintenance of instruments is essential to insure accuracy of results. Calibration intervals can be determined by performing a calibration and then reading values from the original buffer solution used for calibration on a daily basis. When readings fall outside of the expected range then recalibration must occur before this period.

In addition to frequent calibration, instruments require periodic cleaning and proper storage. Follow the manufacturer's guidelines to ensure the accuracy and longevity of these tools. These instruments do have limits in their efficacy and often times need to be replaced every two years.

Fig. 7: AEssense Guardian Grow Manager real-time display of solution EC and pH

Comprehensive Analysis

In many cases, especially when investigating a new site, a more comprehensive water analysis than can be achieved through handheld sensors may be required. In these instances, an analytical lab is required to achieve the necessary results and interpretation.

Water is typically analyzed for irrigation suitability (fig. 8), nutrient solution composition, and potability. Individual components including chemical and physical properties as well as biological and chemical contaminants can be tested for as well. Typically, irrigation suitability tests provide a comprehensive evaluation to evaluate the potential use of a water source. This is often used when investigating a new production site to determine if pretreatment is required.

Monitoring of the nutrient solution can be achieved through an analytical laboratory as well. This analysis can provide verification of the targeted fertigation solution to be delivered to the plants, and should be done occasionally throughout production to ensure you are meeting your set target concentrations.

A & L WESTERN AGRICULTURAL LABORATORIES

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REPORT NUMBER: 00-000-000 CLIENT: 9999-D

SUBMITTED BY:

SEND TO: GROWER:

DATE OF REPORT: 12/12/08 **IRRIGATION WATER ANALYSIS REPORT** PAGE: 1

Sample ID	Lab Number	Sodium Na meq/L	Calcium Ca meq/L	Magnesium Mg meq/L	Carbonate CO_3 meq/L	Bicarbonate HCO_3 meq/L	Chloride Cl meq/L	Conductivity E.C. dS/m	pH	Copper Cu ppm	Iron Fe ppm	Manganese Mn ppm	Zinc Zn ppm
WELL1	63855	6.83	3.14	6.00	0.00	2.95	4.74	1.40	6.6				

Sample ID	Phosphorus P ppm	Potassium K ppm	Nitrate NO_3 ppm	Sulfate SO_4 ppm	Boron B ppm	Dissolved Solids ppm	Adjusted S.A.R.	Langelier Saturation Index
WELL1	0.07	3.9	6	321	0.08	972	3.37	

NOTES:

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

Mike Buttress, CPAg
A & L WESTERN LABORATORIES, INC.

Fig. 8: Sample irrigation suitability analysis.
A & L Laboratories

When using groundwater or surface water sources, analyses of potability may be required to determine if water is safe for human consumption, especially if a municipal water source is not available for use. An evaluation of potabiltiy may include testing for nitrates, coliform bacteria, herbicides, and heavy metals.

Selecting an Analytical Laboratory

When comprehensive analysis is required, you must seek out a qualified testing laboratory. University and private agencies are common options for these services, but names and addresses of testing labs can be found on the Soil and Plant Analysis Laboratory Registry. Local Extension offices or water districts will also be able to provide a list of qualified labs. It is important that the analytical lab that is selected uses only approved standardized methods of analysis.

Sampling

When seeking a quality analysis of irrigation water, it is essential that the water tested represents what will be used as irrigation. To do this make sure that the water originating from a groundwater or surface water source is being discharged at normal flow rates. Sampling containers are relatively unimportant for general irrigation water analysis. Generally, a 16oz sample is sufficient and a polyethylene or polystyrene container (fig. 9) is best as some glass may introduce Boron contaminants (Reed, 1996). Refrigeration is not necessary unless you are seeking information regarding biological components (e.g. potability analysis).

Fig. 9: Water sampling containers
www.salinitymanagement.org

Evaluation of Water: What Do The Results Mean?

Whether testing water using handheld sensors or a qualified analytical laboratory, proper interpretation is essential in making appropriate management decisions. Various references are available that provide tolerance ranges for general plant growth, but it is important to understand and monitor how the various aspects of water quality will impact the specific crops you are producing.

Soluble Salts (EC)

EC or Electrical Conductivity is a common component in nearly all water tests. EC is the measure of a solutions ability to conduct electricity. It is determined by passing an electrical current through a water sample and recording the conductance of electricity between two electrodes. Pure water (free of all charged ions) is a poor conductor of electricity. The greater the ion concentration, the greater the ability to conduct electricity.

EC will provide a reference for all charged ions including those that are not beneficial for plant production. All water sources (except for deionized) will have some salts dissolved in them. The extent of which is important to understand as it can impact plant growth and management.

Fertilizers are essentially soluble salts, and any addition of fertility will increase the conductivity of the solution. Therefore, it is essential to know the starting EC of your water to know limitations on fertilizer before exceeding tolerance levels of your crop. Considering additional contributions from fertilization, the EC of the source water should not exceed 0.5 dS/m for recirculating solutions or 1.5 dS/m for drain to waste solutions (Hendreck, 2005). Depending upon the species and growth stage (table 1), plants will have varying tolerances to a range of EC levels, so it is important to understand your crop requirements.

Relative targets for Cannabis Cultivation

Growth Stage	EC range (mS/cm)
Clones	<1
Seedlings	08.-1.3
Vegetative	1.3-2.0
Flowering	1.2-2.0

Table 1: Relative target levels of EC for cannabis production

How Does EC Differ From TDS?

TDS or Total Dissolved Solids is the total of the nonvolatile solutes dissolved in water (Reed). This value is primarily composed of soluble salts, but can also include soluble organic matter. TDS is estimated by measuring EC and converting it to ppm using three different conversion scales: NaCl, 442 (40% sodium bicarbonate, 40% sodium sulfate, 20% sodium chloride), or KCl. The conversion factors for these three scales are not linear, but generally use a coefficient of 500, 700, and 510 respectively for mS/cm to ppm. To measure actual TDS a sample of water must be weighed, evaporated, and then comparing the weight of residue to the original sample. Though TDS is often used by growers, it is technically not synonymous with EC. TDS (ppm) that is measured from handheld meters is simply an estimate based on EC and one of the scales above.

How Does EC Affect Plant Growth?

Since EC is the measure of soluble salts (or nutrients) in the solution, it can provide an approximate quantity to amount of total fertilizer in the solution, but not specific elements. Therefore, a low EC value could indicate that the crop, depending upon growth stage, may have a reduction in growth because of low nutrient concentration (fig. 10).

An EC value that exceeds the tolerance level for a species may result in water loss, reduced growth, and possibly some phytotoxicity (plant damage as a result of chemical toxicities such as salinity) like tip burn (fig. 10).

Fig. 10: High EC causing marginal necrosis (l), and nutrient deficiency associated with low EC (r).

Water moves in the direction of high salt concentration. Plants are able to regulate the intercellular salt levels to some degree, so that generally water moves into the roots (high solute concentration) from the soil or nutrient solution (lower solute concentration). When the EC (salt concentration) of the solution exceeds tolerance levels (or the concentration in the cells) water no longer moves into the roots (fig. 11).

In this case, if transpiration continues and the plants are not able to replace the loss water, then wilting, reduced plant growth, and possible tissue death may occur. Regular testing can give an indication of total fertility in the nutrient solution to project if plants are receiving adequate nutrients or if excess salts exist limiting water movement into the plants.

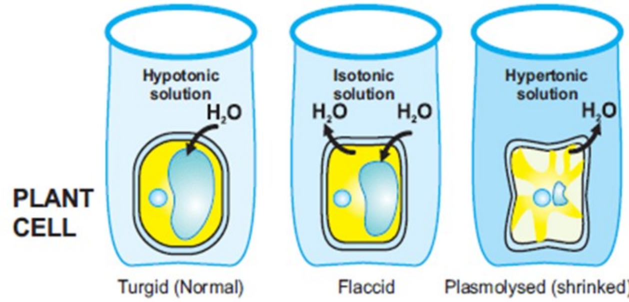

Fig. 11: water movement in and out of plant cells associated with solute concentration. www.quora.com

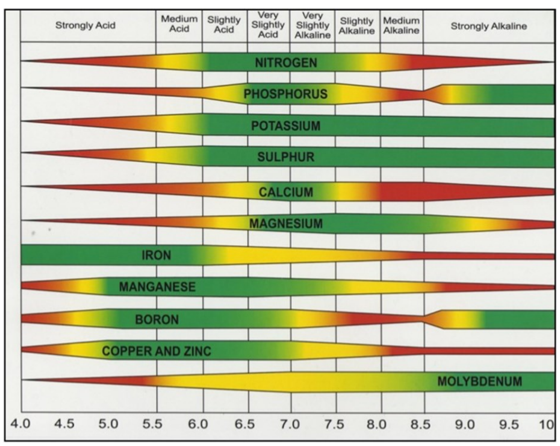

Fig. 12: Relative availability of nutrients at given pH value. ipm.missouri.edu

What Is pH and How Does It Affect Plant Growth?

The pH of a solution is the measure of the concentration of hydrogen (H+) ions. pH values range from 0-14, with 7 being neutral (equal concentration of H+ and OH- ions), values below 7 acidic, and above 7 alkaline. The pH of a solution is measured on a logarithmic scale, so a pH of 5.5 is ten times more acidic than a pH of 6.5 and a pH of 4.5 is 100 times more acidic than a pH of 6.5. Small changes in pH can result in a big impact.

The pH of a solution can be affected by the type of fertilizers used as well as the ions being absorbed by the plants. For example, plants take up nitrogen in two forms: ammonium (NH_4^+) and nitrate (NO_3^-). When plants take up a charged ion, they release an ion with the same charge to maintain a balanced pH within the cells. The use of ammonium based nitrogen fertilizer can lead to a decrease in solution pH as hydrogen ions (H^+) are released by the plant to balance the chemical charge when these NH_4^+ ions are absorbed.

The pH of a solution is of importance to plant growth as it affects the relative solubility and therefore availability of nutrients (fig. 12). Depending upon the species, the target pH range is generally between 5.5 and 6.5. Solution pH above 7.0 can result reduced solubility of phosphorous and micronutrients, potentially causing nutrient deficiencies and reduced plant growth.

Alkalinity

Alkalinity is another component of water that can have an impact on pH, plant growth, and your management strategies. Alkalinity should not be confused with the term alkaline which simply means a pH greater than 7.0.

Alkalinity is a measure of the amount of carbonates and bicarbonates present. Practically speaking, alkalinity is the measure of how resistant the solution is to pH change; the amount of acid required to neutralize the carbonates and bicarbonates.

For example, two solutions may have the same measured pH, but the one with a greater alkalinity will require more acid to neutralize the pH (fig. 12). Alkalnity is generally reported as parts per million (ppm) or milliequivalents (me). The ideal irrigation water will have a total alkalinity of 60-80 ppm which will counteract acidity from fertilizers (Handreck, 2005).

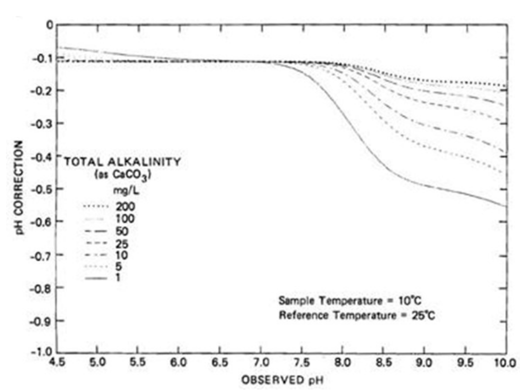

Fig. 13: Impact of total alkalinity on solution pH. www.canada.ca

Other Chemical Properties

When designing a fertigation program, it is important to understand the mineral constituents of the source irrigation water. Some minerals and compounds in source water may have positive contributions to the total fertility. Conversely, some minerals and compounds may have damaging effects and may need to be removed through water treatment methods.

Excessive sodium (Na) can be of concern and may influence irrigation delivery decisions. Sodium concentrations greater than 69 ppm may result in foliar burn limiting the use in overhead irrigation (Reed, 1996). The ability of sodium in water to cause damage is given by the Sodium Absorption Ratio (SAR). Potential toxicity from root assimilation is best judged by the SAR.

Chlorine is commonly added to municipal water supplies to provide downstream treatment of biological impurities can cause concerns for some species. Though chlorine levels of 2 ppm can provide some control of plant pathogens, greater concentrations can be harmful.

Fluoride, which is another common component of municipal water, can cause injury to some crops at concentrations over 1 ppm. Though not typically a problem, it is best to be aware of the potential for phytotoxicity.

Boron is an essential element for plant production, but in can exist in toxic quantities in source water. Boron concentrations are best kept below an upper threshold of 0.5 ppm. Because of the varying tolerance of different species to different components of water, it is essential to know what is in the source water and how it may impact crop production.

Quality of irrigation water*			
Chemical property	Relative hazard		
	None	Mod.	Se-vere
Bicarbonate (ppm)	<122	183-244	>366
Chloride-root (ppm)	<144	144-216	>360
Sodium-root (ppm)	<69	69-207	>207
Lithium (ppm)	<2.5		
Fluoride (ppm)	<1		
Boron (ppm)	<0.3	0.5-1.0	>3
SAR (no unit)	<3	6-8	>9
*Adopted from Ayers and Wescott, and Soil and Plant Laboratory			

Table 2: Components of water quality and relative tolerance levels

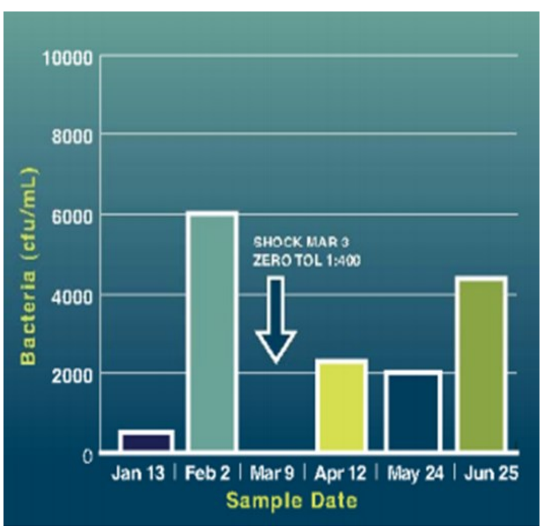

Fig. 13: Monitoring of biological activity after before and after treatment.
hort.ifas.ufl.edu

Biologicals

Though most bacteria and fungi in a water sample are likely benign or even beneficial, pathogens do exist. Waterborne pathogens like Phytophthera and Pythium can cause major crop losses.

As previously mentioned, surface and groundwater sources may also contain pathogens that may limit potability or use on crops in accordance with food safety regulations. Water testing is the only way to know whether an outbreak is being caused by irrigation water or could potentially occur. Testing will help to pinpoint contamination and will ensure that the water treatment system is working properly (fig 13). Contact an approved analytical laboratory to find out sampling capabilities and procedures.

Conclusion

Since water is such an essential component for plant growth and development, it is imperative that a comprehensive evaluation be done before use. Understanding the quality of the source water will help to make informative decisions regarding plant production and site management; design of fertilization program, water treatment, and irrigation methods. Additionally, consistent and continuous monitoring should be done to ensure that the plants are receiving water or a fertigation solution that meets your goals and expectations.

References

Circle of Blue. www.circleofblue.com

California Ag Water Stewardship Initiative

Handreck, K. and Black, N. Growing Media for ornamental plants and turf, 3rd edition. UNSW Press. 2005.

Hochmuth, G.J. Fertilizer Management for Greenhouse Vegetables. Greenhouse Vegetable Production Handbook, Vol. 3. University of Florida Extension. Nelson, Paul V. Greenhouse Operation and Management, 5th Edition. Prentice Hall, NJ. 1998.

Reed, David W. Water, Media, and Nutrition for Greenhouse Crops. Ball Publishing. Batavia, IL. 1996.

U.S. Food and Drug Administration, Food Safety and Modernization Act. Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption: https://www.fda.gov/food/guidanceregulation/fsma/ucm334114.htm

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