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Understanding Water Quality, Water EC, and pH

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Preface

It won't be an exaggeration to say that water management is the most important part in hydroponic cultivation (after all, hydroponic means water-work!). Understanding the water quality and how to manage it, is a crucial task for all growers.

When growing plants in the field, irrigation and fertilization are usually two separate, but related subjects. Fertilizers, which come from a wide variety of solid sources like chicken manure, compost, guano, and synthetic chemicals, are essentially plant nutrients in different forms that need to be broken down to simple chemical compounds to be absorbed by plant roots. However, when growing plants in nurseries and greenhouses, irrigation and fertilization are often combined (fertigation). Plant nutrients are dissolved in irrigation water to feed plants on a regular irrigation schedule. (Please see "Essential plant nutrition" white paper for more information)

For hydroponics, plant nutrients are almost always dissolved in water and delivered to the plant roots with water. A good water management plan is not only crucial to ensure water is available to the plants, but also ensures that nutrients are available to the plants.

Water quality test

Water quality refers to the chemical, physical and biological characteristics of water. Depending on the purpose of the water usage, there are many different treatments and different standards of water quality evaluation. For irrigation water, it is important to know the chemical characteristic as it greatly affects nutrient availability and plant health.

Water quality can be very different depending on the areas and water sources. Irrigation water can come from sources like a river, well, pond, rain water, and tap water, and each has its own chemical characteristics. It is suggested to test the water quality as soon as a new cultivation is established. In some extreme cases, plant production is simply unfeasible due to the amount of pretreatment needed from bad water quality..

Many governmental and private laboratories conduct water quality analysis for different purposes, and one can simply send the water sample to the lab and pay to obtain the reports. Once the water quality pattern is established, water only needs to be tested every few years. For irrigation water, these are usually the must-know water chemical characteristics:

1. Water Electric Conductivity (EC) and Total Dissolved Solids (TDS)

EC refers to the electrical conductivity of the water solution. When the water is pure without any dissolved solutes, it conducts electricity naturally. The amount of electricity that can pass through water is influenced by how many ions are dissolved in the water solution. By measuring EC, we can get an idea of how much ionic nutrients are in the water. For example, seawater's conductivity is one million times higher than pure (deionized) water, because there are a lot of ions dissolved in the seawater, especially sodium (Na), chloride (Cl), magnesium (Mg), sulfate (S) and calcium (Ca).

The value of water EC can be obtained with an electrical conductivity (EC) meter. Typically, the meter probe has two electrodes that are placed in the water sample solution to measure the conductance of electricity between them. The unit for EC is **mmho/cm** (milli-mho per centimeter), which refers to the electrical resistance between two points, or distance. Two other terms for EC measurement are also popular: **mS/cm** (milli-Siemen per centimeter) or **dS/m** (deci-Siemen per meter), and **1 mmho/cm = 1 mS/m = 1 dS/m.**

The EC meters are relatively simple and stable, and can be purchased from most hydroponic shops. Although the EC units might look confusing, they are actually easy to calculate and interpret as a linear correlation. The higher the EC, the more solute salts and ions are in the water. Many horticultural guidelines provide the upper acceptable EC level for various plants depending on the species and growing stage. For example, the EC level for irrigation seedlings cannot be higher than 0.75 dS/m, but for older crops in general, it is 1.5 dS/m.

For hydroponics, water EC provides an important indication of the amount of nutrients dissolved in the water solution. Many hydroponic growers use **total dissolved solids (TDS), and the unit ppm (parts per million) to refer to the nutrient concentrations**. However, this is a misnomer; people often do not realize that TDS meters cannot directly measure how many ppm of nutrients ions are in the water. In fact, the TDS meter can only get this number by converting the EC of the water solution to ppm through an estimated calculation.

EC *does not* tell us the exact ppm of ions in the nutrient solution for several reasons. EC meters can only measure the electric conductivity as a whole; different ions have different electric conductivity when dissolved in water. Moreover, EC meters do not measure non-charged molecules like urea nitrogen. TDS meters can only give us a rough idea of how much ppm is in the water based on proprietary calculations from the manufacturer. Therefore, TDS meters from different brands will show different EC-TDS conversions depending on their reference solutions (Table 1).

Table 1. An example of three different conversions from EC (mS/cm) to TDS (ppm).

EC (mS/cm)	TDS NaCl (ppm)	TDS KCl (ppm)	TDS 640 (ppm)
0.1	50	55	64
0.5	250	275	320
1	500	550	640
1.5	750	825	960
2	1000	1100	1280
2.5	1250	1375	1600
3	1500	1650	1920

To calculate:

- EC (mS/cm) * 1000 * 0.5 = TDS NaCl
- EC (mS/cm) * 1000 * 0.55 = TDS KCl
- EC (mS/cm) * 1000 * 0.64 = TDS 640

Unfortunately, there are no cheap and reliable sensors that can detect the concentration of each individual ion dissolved in the water at this point in time. There are ways to measure each ion at professional laboratories, but they are often costly and cannot be used as an everyday practice. While EC meters do not tell us the exaction concentration of the water, it can still provide an important and reliable indication for nutrient management.

Depending on the plant type and its growing stage, the EC of the nutrient solution has to be maintained at a certain range to ensure the plants can get enough nutrients. Low EC results in slow growing plants with disorders such as leaf yellowing, whereas excessively high EC can lead to toxicity and poor plant growth.

2. Water pH

The pH is a numeric scale from 0-14 to determine the acidity and basicity of the water solution. The pH of pure water is neutral, pH=7. Solutions with pH less than 7 are acidic and solutions with pH more than 7 are basic. For example, the pH of lemon juice is around 2 and the pH of sea water is around 9.

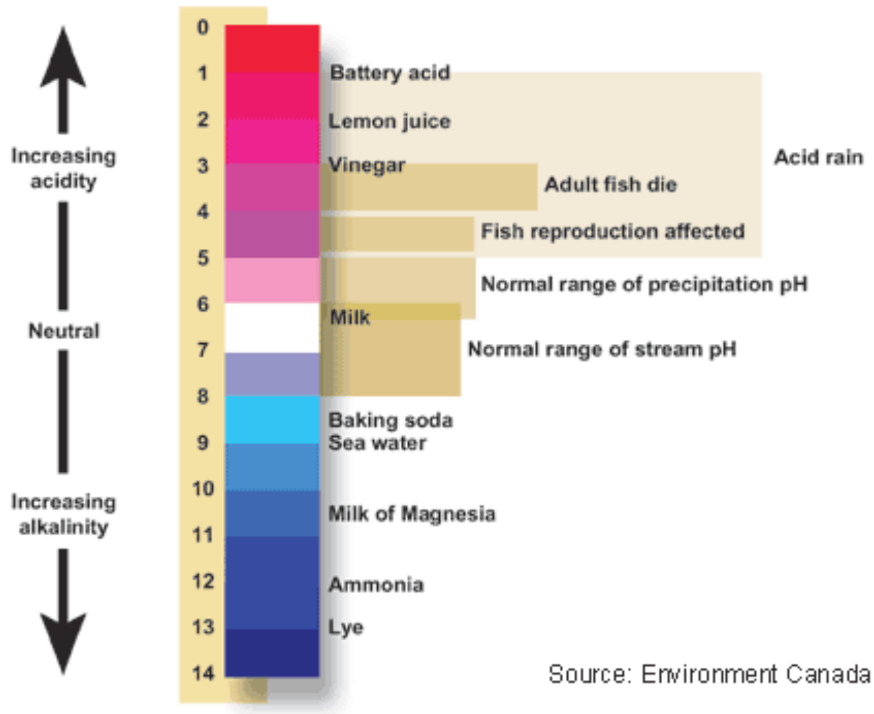

Figure 1. Diagram of pH, US Geological Survey (water.usgs.gov)

pH is really a measure of the relative amount of free hydrogen (H+) and hydroxyl (oH-) ions in the water. The solution that has more hydrogen ions is acidic, whereas a solution that has more hydroxyl ions is basic. pH is measured in "logarithmic units", meaning each number represents a 10-fold change in the acidity/basicness of the water. Water with a pH of 5 is ten times more acidic than water having a pH of 6.

The pH meter usually comes with a glass probe that contains two electrodes that measures voltage. Different from an EC meter, the glass bulb of a pH meter has one electrode that is contained in a liquid with a fixed acidity, and the other electrode responds to the acidity of the water solution. A voltmeter in the probe measures the difference between the voltages of the two electrodes, and then translates the voltage difference into pH.

Compared to an EC meter, a pH meter is relatively unstable and requires regular maintenance and calibration. The pH bulb needs to be stored in a proper solution to remain hydrated. Different pH meter manufacturers offer different solutions, but in most cases it is potassium chloride (KCl) solution. The lifespan of a pH meter can vary from a few months to a few years depending on the frequency of use and maintenance. It is very important to be aware of the accuracy of a pH meter and to check it regularly.

The pH of the solution plays an important role for plant nutrient uptake. **Water pH affects essential nutrients' availability**; in other words, when the water pH is out of range, plants cannot absorb nutrients even when there is plenty in the water. The desirable water pH for a hydroponic system is 5.6-6.2.

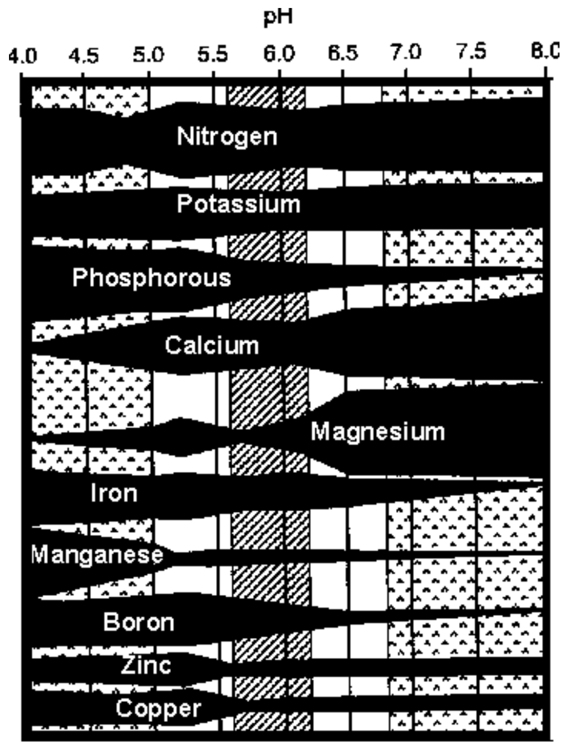

Figure 2. The availability of plant essential elements in relation to water pH in hydroponic or soilless culture. The larger the band is, the more available the elements are. The water pH for hydroponic cultivation should be maintained around 5.6-6.2 the whole time.

When the water pH is higher than 6.2, the availability of phosphorus (P), iron (Fe), manganese (Mn), boron (B), zinc (Zn), and copper (Cu) decrease. When the water pH is lower than 5.6, calcium (Ca) and magnesium (Mg) become unavailable. The pH of the nutrient solution has to be monitored constantly, as it only takes a short time for a pH that's out of range to have a drastic impact on plant growth, especially for fast growing plants.

3. Alkalinity

Alkalinity refers to the capacity of water to neutralize acid, which is also commonly known as "buffering capacity". This capacity is mainly influenced by how much carbonates and bicarbonates (H2CO3, HCO3, and CO3) are in the water solution. The main source of alkalinity in water is calcium carbonate (CaCO3), which are derived from carbonate rocks (limestone).

Water alkalinity has a significant effect on the pH of the water. If the water alkalinity is high, it is very difficult to adjust the water pH to the right range, because the buffering capacity of the water itself is very strong. In such conditions, growers often have to inject a large amount of acid to bring down the water pH to the optimum range.

Water alkalinity is generally reported as mill-equivalent per liter (me/L) or parts per million (ppm) of equivalent calcium carbonate. One me/L of alkalinity is equal to 50 ppm of equivalent calcium carbonate. The critical value for alkalinity depends on the crop variety and the length of the crop production period, as the high alkalinity will gradually bring up the pH over time.

Water alkalinity reading higher than 1.5 me/L is an indicator that some action is required to bring down the alkalinity. If this is the case, it is suggested to add acidic fertilizer or simply inject acid into the water. For alkalinity higher than 8 me/L, reverse osmosis is usually required.

4. Hardness

Water hardness is a measure of how much calcium (Ca) and magnesium (Mg) is in the water. When the water alkalinity is high, the water hardness is probably also high and should be tested. Water hardness is expressed as me/L. When the water hardness exceeds 3 me/L, the water can cause health problems.

If the water exceeds 3me/L, make sure to check the calcium and magnesium concentrations in the water. Calcium and magnesium are both essential plant nutrients and have similar chemical properties. They both have two outermost electrons to form cations with a 2+ charge (Ca^{2+} and Mg^{2+}) and their ratio in the water influences uptake mechanisms.

A proper ratio of calcium to magnesium is 3-5:1. For each ppm of magnesium, there should be 3-5 ppm of calcium in the water. If the calcium level exceeds this, the uptake of magnesium can be blocked. If the calcium concentration is lower than the suggested ratio, calcium uptake itself can be blocked. The plants will often show calcium deficiency symptoms if this is the case.

5. Specific elements

In some cases, too many specific elements may have a negative impact for plants; this is especially true for hydroponic cultivation. Despite these elements being essential for plant growth, plants only need them in such miniscule amounts that it's very difficult for growers to adjust them during application. In such cases, many growers will choose to use reverse osmosis system to get rid of all the dissolved ions to start from scratch.

Table 2. The maximum tolerable levels of specific elements for most crops:

Sodium (Na)	50 ppm	**Zinc (Zn)**	0.3 ppm
Chloride (Cl^-)	70 ppm	**Copper (Cu)**	0.2 ppm
Chlorine (Cl_2)	2 ppm	**Borate (BO_3)**	0.5 ppm
Iron (Fe)	4 ppm	**Fluoride (F^-)**	0.5 ppm
Manganese (Mn)	0.5 ppm	**Lithum (Li)**	0.5 ppm

Reference:

US Geological Survey: water (www.water.usgs.gov)

Paul V. Nelson. 2012. Greenhouse Operation and Management, 7th edition. Pearson Education Inc.