Alkalinity in Soilless Substrates

Figure 1. Typical interveinal chlorosis symptoms of the upper leaves caused by a high pH induced iron deficiency in petunia

What's the difference between alkalinity and pH? Are they related in any way? Understanding how these two things affect substrate can lead to better prevention of common nutritional deficiencies

By Roberto G. Lopez, Claudio Pasian and Michael V. Mickelbart

Yellow, pale or white leaves on the youngest growth of greenhouse and nursery crops are often signs of nutritional deficiencies. In certain instances, the problem may be a lack of a specific nutrients in the substrate; in others, the nutrients may be present, but high substrate pH makes them unavailable to the plant.

It's common practice to add sulfuric (H_2SO_4), phosphoric (H_3PO_4), nitric (HNO_3) or citric ($H_3C_6H_5O_7$) to irrigation water to neutralize alkalinity and lower the substrate pH. To properly manage irrigation water and substrate pH, it is important to have a clear understanding of the underlying causes behind high substrate pH. Irrigation water alkalinity, rather than pH, is typically the source of the problem. The purpose of this article is to help growers differentiate between high pH and high alkalinity, and explain management strategies for managing alkalinity in soilless substrates.

Some Definitions

In order to proceed, we must review the definition of pH. It is a measure of the concentration of hydrogen ions (H^+) in a solution. Examples of solutions are tap water and the water in the rooting substrate of container plants. The pH scale ranges from 0 to 14. A value of 7.0 is neutral. Pure water has a pH of 7.0. Acidic solutions have pH values less than 7.0, and basic (also referred to as alkaline) solutions have pH values greater than 7. In general, the pH of water for irrigating greenhouse and nursery crops should be between 5.5 and 7.

Alkalinity is a measure of the buffering capacity, or the capacity of a solution to neutralize acids. Examples of the primary dissolved bases that contribute to alkalinity in a solution are carbonates (e.g., calcium carbonate) and bicarbonates (e.g., calcium, magnesium, and sodium bicarbonate). Because of the presence of limestone in many Midwest, Great Plains, western New York, Florida and Canadian prairie soils and aquifers, bicarbonates are commonly found in groundwater. Other minor contributors include dissolved ammonia, borates, phosphates and silicates. In practice, the main contributors to alkaline water are carbonates and bicarbonates.

The confusion between high pH and high alkalinity stems from the fact that water is called "alkaline" if its pH is greater than 7, and it is said to have "high alkalinity" if it has a high concentration of bases. However, high pH does not necessarily correspond to high alkalinity and vice versa, although the two often occur simultaneously in irrigation water. Water alkalinity can have a significant effect on substrate pH, but the pH of irrigation water has a minimal effect on the pH of the solution in the substrate. Irrigating crops with water high in alkalinity has the same effect as adding lime to the substrate. The bottom line: Growers need to know what their water alkalinity is then decide whether treatment is necessary.

The units that quantify alkalinity are another possible source of confusion for growers. Alkalinity can be expressed as equivalents of alkalinity (meq/L) or concentration (ppm or mg/L) of total carbonates (as $CaCO_3$), bicarbonate (HCO_3^-), or hardness (Ca + Mg).

Water hardness and alkalinity are not strictly related, but because alkaline water is typically high in calcium and magnesium carbonates, hardness is often a good approximation of alkalinity. This is because these two elements are often correlated with high levels of:

- Carbonates (CO_3): commonly calcium carbonate, $CaCO_3$
- Bicarbonates (HCO_3^-): commonly calcium

bicarbonate, $Ca(HCO_3)_2$; sodium bicarbonate, ($NaHCO_3$); or magnesium bicarbonate, $Mg(HCO_3)_2$

Because different water testing labs use different units to report water alkalinity, it is important for growers to know how to use and interpret these values to calculate how much acid they need to add to their irrigation water.

Alkalinity's Effects

When substrate pH is high, some nutrients won't be available to plants even if they're present in the substrate. The most common deficiency induced by high substrate pH is iron deficiency, which is characterized by interveinal chlorosis (yellowing between the veins) of the upper (new) leaves (Figure 1). Severe iron deficiency may appear as yellowing or whitening of entire new leaves (Figures 2 and 3).

Most soilless substrates used for nursery and greenhouse crops have an initial pH below 7. This is because the components of these mixes, such as peat and bark, have low pH values. Therefore, it takes some time for high-alkalinity irrigation water to affect the media. There are two primary things that determine how quickly a change in substrate pH can occur: container volume and time. The substrate in a small container has a low buffering capacity against changes in pH; therefore, plants growing in small containers that are irrigated with high-alkalinity irrigation water will show deficiency symptoms much faster than plants growing in larger containers irrigated with the same water.

High-alkalinity water is more likely to affect crops held in the nursery or greenhouse for months or years. That is because any buffering the media initially provides is eventually overwhelmed by the volume of high alkalinity water that builds up carbonates and bicarbonates in the substrate over time. As the media's buffering capacity diminishes, newly unfolding leaves will exhibit deficiency symptoms. Many micronutrients, such as iron, manganese, boron and zinc, cannot move around in a plant once they have been initially taken up. If new leaves develop when iron uptake by the roots is limited by high substrate pH as a result of irrigating with highly alkaline water, the new leaves will develop iron deficiency symptoms. Plants cannot mobilize iron from old to new leaves, so new growth develops the deficiency first.

Iron-Inefficient Plants pH: 5.6-6.2	General Group pH: 5.8-6.4	Iron-Efficient Plants pH: 6.0-6.6
Argyranthemum, azalea, bacopa, brachycome, calibrachoa, dianthus, diascia, nemesia, pansy/viola, petunia, rhododendron, scaevola, snapdragon, verbena (fine-leafed varieties)	Angelonia, begonia, chrysanthemum, fuchsia, helichrysum, heliotrope, heuchera, geranium (ivy), impatiens, poinsettia, tomato, verbena (broad-leafed varieties)	Lisianthus, geranium (seed and zonal), marigold, New Guinea impatiens

Table 1. Substrate pH guidelines for some common greenhouse and nursery plants (Source: Ball Redbook Crop Production)

Certain crops, such as petunia and calibrachoa, have roots that don't absorb iron efficiently. For iron-inefficient crops (see Table 1), maintain pH on the lower side (5.6-6.2) to avoid iron deficiency.

On the other hand, if the pH of the substrate is too low, some crops (such as geraniums, marigolds and lisianthus) may suffer toxicity from an excess of nutrients such as iron and manganese because these nutrients become readily available and are taken up at lower pH values.

Keep Checking

It is important to remember that water alkalinity is not a constant value. It can change seasonally or over time. Growers should test their water at least once or twice a year. In general, surface water from rivers and lakes is less likely to have high alkalinity levels than water from wells. If your water source is an aquifer or well, you may see your water alkalinity increase during droughts and decrease during periods of heavy rain.

It is difficult to say a specific measure of water alkalinity is too high because several factors — including water alkalinity, fertilizer potential acidity/basicity, the amount and type of lime added to the substrate mix, substrate components and the crop itself — affect substrate pH.

Growers can lower water alkalinity by correctly acidifying irrigation water, thereby reducing the concentration of bicarbonates. More precisely, injecting acid into the irrigation water neutralizes alkalinity and forms carbon dioxide and water.

When selecting an acid, consider:

- Ease of use
- Safety
- Cost
- Nutrients (nitrogen, phosphorous,

Figure 2. Severe iron deficiency results in chlorotic (almost white) young leaves

Figure 3. Severe iron deficiency (interveinal chlorosis and leaf bleaching) as a result of high irrigation water alkalinity and increased substrate pH

and sulfur) the acid provides

Sulfuric acid is the most common acid growers use because it is inexpensive and relatively safe.

Assessing Chelates

Iron chelates can quickly "green up" crops, which can be desirable before shipping. However, applying iron chelates does not solve the root of the problem: high substrate pH.

If growers do not lower substrate pH to the level appropriate for the crop, then iron deficiency will reappear in time. Furthermore, iron chelates supply only iron, not the other micronutrients (such as manganese, zinc, boron, or copper) that may be unavailable because of high pH levels.

Chelates are available as foliar sprays or substrate drenches. Foliar sprays are the only way to green up mature leaves with severe iron deficiency. After applying an iron chelate, the leaves must be washed off lightly with clear water because extended contact with the chelating agent can cause phytotoxicity, often evident as brown spotting of leaves (Figure 4).

Figure 4. Foliage must be lightly washed off with clear water after iron chelate applications, as certain species (such as this begonia) will exhibit phytotoxicity.

The Take-Home

Important points to remember and act on:

- Understand the difference between water pH and water alkalinity.
- Know the pH and the alkalinity of your irrigation water.
- Remember that water alkalinity has a greater effect on substrate pH than water pH.
- Use alkalinity to determine how much acid to add to irrigation water, not pH.

Roberto Lopez is an assistant professor and floriculture extension specialist at Purdue University. Claudio Pasian is a professor of floriculture at The Ohio State University. Mike Mickelbart is an assistant professor and nursery management specialist at Purdue University. They can be reached at rglopez@purdue.edu; pasian.1@osu.edu; and mmickelb@purdue.edu, respectively.

Calculating Acid Applications

Researchers from North Carolina State University, the University of New Hampshire and Purdue University developed an Alkalinity Calculator. With financial support from the Fred C. Gloeckner Foundation, it has been converted into a user-friendly online calculator called "ALKCALC," which can be accessed at: **extension.unh.edu/Agric/AGGHFL/Alkcalc.cfm.**

Growers can enter their water pH and alkalinity into ALKCALC and then select an acidifying agent to reach a target pH or alkalinity. The online spreadsheet also calculates many nutrients the acids provide, and calculates acidification costs based on the price per gallon of acid.

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