Commercial Greenhouse and Nursery Production

Purdue Department of Horticulture and Landscape Architecture
www.hort.purdue.edu

Ohio State University Horticulture and Crop Science
www.hcs.osu.edu

Purdue Floriculture
flowers.hort.purdue.edu

Alkalinity Management in Soilless Substrates

Roberto G. Lopez and Michael V. Mickelbart, Purdue Horticulture and Landscape Architecture

Claudio Pasian, Ohio State University Horticulture and Crop Science

EXPERT REVIEWED

Greenhouse and nursery growers often assume yellow and pale leaves are signs of nutritional deficiencies. Sometimes, however, the problem may be due to a lack of specific nutrients in the substrate — in other cases, the nutrients may be present but high substrate pH makes them unavailable to the plant.

Growers commonly add sulfuric or other acids to irrigation water to help lower substrate pH or apply iron chelates to quickly "green up" their crops before shipping. Unfortunately, growers often do not have a clear understanding of the underlying causes behind increased substrate pH — water alkalinity, rather than water pH, is typically the source of the problem.

The purpose of this publication is to help growers differentiate between high pH and high alkalinity and how to manage alkalinity in soilless substrates.

What Is pH?

The pH scale measures the concentration of hydrogen ions (H+) in a solution. Examples of solutions are tap water and the water in the substrate inside a pot. The pH scale ranges from 0 to 14. A value of 7.0, which is pure water, is neutral. Values less than 7.0 are called acidic, and values greater than 7 are called basic or alkaline.

In general, the pH of water for irrigating greenhouse and nursery crops should be between 5.0 and 7.0.

What Is Water Alkalinity?

Water *alkalinity* is a measure of the capacity of a solution to neutralize acids. Water alkalinity also is referred to as the buffering capacity of water.

Examples of bases that contribute to alkalinity in a solution are carbonates, bicarbonates, ammonia, borates, phosphates, and silicates. In practice, the main contributors to alkaline water are carbonates and bicarbonates, which are common in groundwater in the Midwest. Irrigating your crops with water high in alkalinity has the same effect as adding lime to the substrate.

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 are related in irrigation water. Water alkalinity can have a large and significant effect on substrate pH, but the pH of irrigation water has a minimal effect on the pH of the solution in the substrate. The bottom line is that growers need to know what their water alkalinity is, and then

Table 1. Various testing labs report alkalinity using different units. Hardness can also be used as an indicator of alkalinity.

Measure	Typical Reported Units
Alkalinity	meq/L*
Total Carbonates (as $CaCO_3$)	ppm = mg/L
Bicarbonate (HCO_3^-)	ppm = mg/L
Hardness (Ca + Mg)	ppm = mg/L

*meq/L can be converted to ppm $CaCO_3$ or mg/L $CaCO_3$ by multiplying meq/L by 50.05.

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 or concentration (ppm or mg/L) of carbonates (Table 1).

Another method for reporting alkalinity is as total calcium plus magnesium. Water *hardness* may be reported as the total ppm of calcium (Ca) and magnesium (Mg). Water hardness and alkalinity are not strictly related, but because alkaline water is typically high in Ca and Mg 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 units are used to report water alkalinity, it is important for growers to know how to use these values to calculate how much acid they need to add to irrigation water.

Why Is Water Alkalinity Important?

High water alkalinity results in high substrate pH. When substrate pH is high, some nutrients are unavailable to plants even if the nutrients are present in the substrate.

The most common deficiency caused by high substrate pH is iron deficiency, which is characterized by interveinal chlorosis of the leaves (yellowing between the veins), especially new leaves (Figures 1, 2, and 3). If severe, iron deficiency may appear as yellowing or whitening of entire new leaves.

In crops that are held for prolonged periods, older leaves are often green because the media is able to

Figure 1. *Typical symptoms of iron deficiency in petunia.*

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

Table 2. Media pH guidelines for some common greenhouse plants.

Iron Inefficient Plants pH 5.4 to 6.2	General Group pH 5.8 to 6.4	Iron Efficient Plants pH 6.0 to 6.6
bacopa	chrysanthemum	geranium (seed and zonal)
calibrachoa	geranium (ivy)	marigold
nemesia	impatiens	New Guinea impatiens
pansy	poinsettia	lisianthus
petunia		
snapdragon		
scaevola		

Source: Chapter 4 (“Managing pH for Container Media”) of Ball Redbook Crop Production, Volume 2, 17th Edition by Paul Fisher.

Figure 3. *Severe iron deficiency as a result of high irrigation water alkalinity.*

buffer the alkalinity of the irrigation water. However, as the media’s buffering capacity diminishes over time, newly unfolding leaves will exhibit deficiency symptoms (Figure 3).

Many micronutrients (such as iron, manganese, and zinc) are immobile within the plant — that is, they 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 alkalinity, the new leaves will develop iron deficiency. Plants cannot move (mobilize) iron from old leaves to feed new leaves, so new growth expresses the deficiency first.

Certain crops, such as petunia and calibrachoa, have roots that are inefficient at absorbing iron. For the iron inefficient group, maintain pH on the lower side (pH 5.4-6.2) to avoid iron and manganese deficiency (Table 2).

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

At the same time, if water alkalinity is very low, the substrate pH can decrease, especially when using acidic fertilizers such as ammonium-based products. In areas where water alkalinity is low, growers should keep substrate pH a bit higher for iron-efficient plants (pH 6.0 to 6.6) to avoid toxicity of iron and manganese (Table 2).

Water Alkalinity Varies

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 a year.

In general, surface water from rivers and lakes is less likely than water from wells to have high alkalinity levels. If your water source is an aquifer or well, you may see your water alkalinity change during droughts or during periods of heavy rain.

What Is a High Alkalinity Level?

It is difficult to say a specific measure of water alkalinity is too high because several factors (including water alkalinity, fertilizer pH, the amount and type of lime added to the substrate mix, substrate components, and the crop) affect substrate

Table 3. General guidelines of upper and lower alkalinity limits.

Alkalinity	Water	Bicarbonate ppm
Low	Soft	<80 ppm (mg/L)
Moderate		100–200 ppm (mg/L)
High	Hard	>200 ppm (mg/L) >60 ppm (mg/L) Ca >25 ppm (mg/L) Mg

pH.

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.

Container size also can be a factor. Small volumes of substrate have a lower buffering capacity. In small containers, high alkalinity irrigation water can quickly affect the substrate pH.

A general rule is that irrigation water with alkalinity of 120 ppm calcium carbonate is likely to cause high substrate pH problems. At such levels, growers should consider acidifying irrigation water. Table 3 provides general guidelines for upper and lower alkalinity limits.

But remember, these values are not absolute.

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.

Acids commonly injected into irrigation water to neutralize water alkalinity include sulfuric (H_2SO_4), phosphoric (H_3PO_4), nitric (HNO_3), and citric ($H_3C_6H_5O_7$).

When selecting an acid, consider:

- Ease of use
- Safety
- Cost
- Nutrients (nitrogen, phosphorous, and sulfur) the acid provides

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

How Much Acid Should Be Applied?

Researchers from the University of New Hampshire, North Carolina State University, and Purdue University developed the online Alkalinity Calculator:

extension.unh.edu/Agric/AGGHFL/Alkcalc.cfm

Growers can enter their water pH and alkalinity into the Alkalinity Calculator program, and then select an acidifying agent (sulfuric, phosphoric, or nitric acid) 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.

Can Iron Chelates Reduce Alkalinity?

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, in time, reappear. Furthermore, iron chelates only supply iron, not the other micronutrients (such as manganese, zinc, or copper) that may be unavailable due to high pH levels.

Growers who do decide to use chelates can apply the product as a foliar spray or as a substrate drench. Foliar sprays are the only way to green up mature leaves that have severe iron deficiency. After an iron chelate foliar spray, growers must mist off the leaves with clear water because extended contact with the chelating agent can cause phytotoxicity, which often is evident as brown spotting of leaves.

How Do I Manage Substrate pH?

Growers can record and plot the weekly substrate

Table 4. *Corrective measures for pH substrates.*

Lower Substrate pH	Raise Substrate pH
Proper water acidification	Discontinue water acidification
Use acid-residue (ammonium nitrogen or sulfur) fertilizers if plants are tolerant	Use basic-residue fertilizers
Drench with aluminum sulfate to rapidly reduce pH*	Inject potassium bicarbonate*

** Should only be performed in severe cases as it can cause toxicity problems.*

pH of their crops. The record can include upper and lower decision points. It is important to remember that all nutrients are readily available when soilless substrate pH is between 5.4 and 6.2, but each plant species has an optimal pH range. Table 4 includes measures to lower or increase substrate pH.

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 acidity or pH
- Use alkalinity to determine how much acid to add to irrigation water, not pH

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