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Best Practices in Chlorination

Irrigation Water Treatments

Chlorination is an effective water treatmeant for control of plant pathogens. We can increase efficacy and reduce risk of phytotoxicity by following some simple practices.

Chlorine is commonly used to control waterborne pathogens in irrigation. Chlorine is a low cost option for treating irrigation water, it has been studied more than any other water treatment option, and has a residual control through the irrigation system. Despite these benefits, many growers fear using chlorine because of the risk of phytotoxicity. In this Alert, we will discuss how to safely use chlorine as a water treatment in irrigaiton.

Chlorine chemistry

Chlorine oxidizes and chlorinates organic matter. These modes of action do not specifically target microorganisms, they affect any organic molecules, including plants and chelates (e.g. iron EDTA). That is why proper management is needed to prevent phytotoxicity or affect nutrient programs.

Free chlorine is the collective concentration of hypochlorous acid (HOCl, a strong oxidizer that predominates below pH 7.5), and hypochlorite ion (OCl-, a weak sanitizer that predominates at higher pH). Total chlorine includes the sum of combined forms of chlorine (e.g. chloramine) and free chlorine. We can easily measure both forms of chlorine in-house. Suppliers like Hanna Instruments, Orion ThermoScientific or Hach® provide multiple options to measure chlorine in-house.

Chlorine is applied as liquid (hypochlorous acid or sodium hypochlorite), solid (calcium hypochlorite, or gas (figure 1). Electrochemically activated water (also known as electrolyzed oxidizing water) also results in the formation of abundant hypochlorous acid, specially when the pH is neutral. Independently of the application form, the efficacy and safety of chlorine application is, in general, the same.

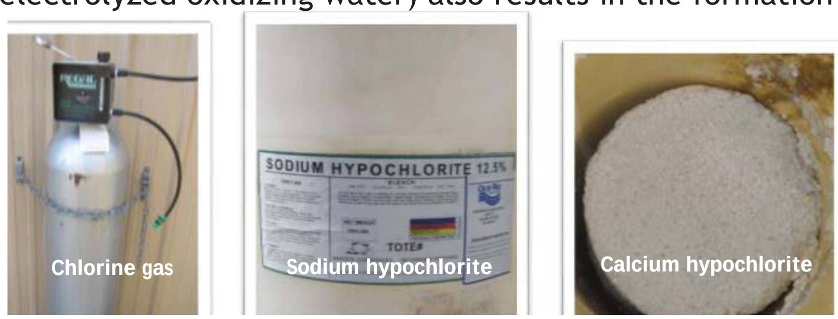

Figure 1. Some example of commercial chlorine options commonly used in greenhouses.

Residual dose

Plant pathologists recommend a dose of 2 ppm of free chlorine to kill *Pythium* and *Phytophthora* zoospores, most bacteria, and some viruses. Concentrations greater than 2 ppm are required to control fungi (e.g. *Fusarium* and *Rhizoctonia*), other life stages of water molds (e.g. *Pythium* mycelium or resting spores), algae and nematodes. It is important to identify if chlorine is the best option for the problem you aim to target. To find more information about the efficacy of water treatments to control microbes in irrigation go to: backpocketgrower.com> tools> Waterborne solutions.

Research conducted on annual ornamentals in our lab (Figure 2) and on deciduous shrubs at the University of Guelph has established that a residual concentration of 2 ppm in irrigation water is also the safe dose for most crops. Doses above 2 ppm can cause severe phytotoxicity symptoms.

Figure 2. Impatiens *walleriana* Super Elfin Lipstick (Ball Premier Line) treated with 0, 2, 4, 8, 16 or 32 ppm of free chlorine in the form of sodium hypochlorite. Plants were irrigated with 200-300 ml of water three times per week for four weeks. Irrigation was applied directly in the growing media without wetting the foliage. Reduction in plant biomass and chlorophyll were observed when plants were treated with chlorine at 4ppm or higher.

Injected dose

Chlorine demand is the difference between the added chlorine dose and the residual concentration measured at a given contact time and at a given pH. Chlorine demand represents the decline of chlorine caused by contaminants such as organic matter, microorganisms, and ammonium in a water source from an applied active ingredient concentration to a lower residual level.

Pond water and recirculated water tend to have high organic matter residues and microbial load. Chlorine quickly reacts with the organic matter. Therefore, these two water sources have high chlorine demand. Recirculated nutrient solutions will also have high chlorine demand because the chlorine will interact with organic chelates and the ammonium-N in the nutrient solution.

Growers aim to have a 2 ppm residual concentration at the emitter. In most cases, growers will inject chlorine concentrations above 2 ppm to satisfy the chlorine demand of the water.

Estimate how much chlorine to inject in your own water:

1. Collect water from the source in a bucket.
2. Inject a known amount of chlorine (for ex. 5 ppm).
3. Estimate how much time it would take for the water to travel from the injection point to the emitter, and then allow for that much contact time in the bucket.
4. Measure the residual concentration.

If the residual concentration is out of range (too high or too low), then repeat the measurement in the bucket (with fresh water) and change the initial chlorine concentration (Step 2) until the residual concentration is close to 2 ppm chlorine.

If the residual concentration is ~2ppm, then inject the initial chlorine concentration in your storage tank or inject in-line and measure the residual concentration at the emitter. Adjust if needed.

Good Practices to increase efficacy and reduce risk of phytotoxicity

Filter, sanitize, fertilize… in that order

Organic matter and fertilizers will interact with chlorine (increase chlorine demand of the water) and reduce its oxidizing power. Dr. Paul Fisher (University of Florida) measured that after two minutes contact time chlorine concentration went from 2.0 to 1.5 ppm when the solutions contained 50 ppm peat and from 2.6 ppm to 0.1 ppm when the solution contained 200 ppm-N in the form of ammonium. When designing a chlorine injection system, always put a filter before the chlorine injector and then inject the fertilizers.

Adjust the pH of the solution to 6.0

The efficacy of chlorine is pH-dependent. Hypochlorous acid, the strongest oxidizer form derived from chlorine, predominates below pH 7.5. In contrast, hypochlorite ion is a weak sanitizer and predominates at higher pH. Oxidation reduction potential (ORP) is a measurement of the oxidizing power of a solution. ORP is greater in solutions with pH under 7.5 compared with solutions at higher pH. Dr. Lang et al. (Colorado State University) evaluated Pythium mortality in solutions at pH ≤6.6 or ≥7.7 treated with 0.5 ppm chlorine. The solution with lower pH had an ORP of 764mV and 100% mortality compared with the solution at pH>7.7 which had 691mV and ~70% mortality. Plant pathogen mortality increases as pH decreases and ORP increases in a chlorinated solution.

Extend contact time

Chlorine efficacy is improved with extended contact time. Chlorine concentrations of 0.5 - 1.0 ppm at extended contact times are also effective in controlling many plant pathogens (See Waterborne solutions). Growers can target to have residual concentrations of < 2ppm chlorine and extend the contact time to achieve high level of control.

Most sanitizers depict a tradeoff between concentration and contact time. Whereby a higher concentration requires a shorter contact time for pathogen control, and conversely the efficacy of a low concentrations is increased with a longer duration of exposure.

An easy wat to extend contact time is by injecting sanitizers direclty in storage tanks and leave them overnight. This method significantly increases contact time and efficacy of control.

Monitor pH, ORP, and active ingredient

Combined measurement and control of pH, ORP, and active ingredient concentration provide the most efficient, reliable, and safe chlorination system. Simply ensuring that the pH is under 7.5 prior to injecting chlorine will increase the chlorine efficacy. ORP is easy to measure inline (Figure 3) or with a handheld meter (similar to pH meter). We should aim to have an ORP between 650 to 800 mV. Free chlorine can be measured with the titration meters mentioned earlier.

Figure 3.Example of an inline automated pH (left) and ORP (right) meter in a commercial greenhouse.

Monitor efficacy of control

Measuring the relative concentration of microbes before and after treatment is a useful indicator of whether the treatment is reducing populations. Total microbial load can be qunatified by most plant diagnostic labs (e.g. QAL) or on-site. Growers measure microbial load onsite with dehydrated media specific for aerobic bacteria (3M Petrifilms). The goal of sanitizing irrigation water is to reduce pathogen populations and general microbial load, not to sterilize the water. Therefore, we can expect to see some bacteria after treatment. If the system is working, microbial counts after treatment should be significantly lower than before treatment. If the numbers are about the same, then we should go back to check the stock solution, injection system, pH, etc. For more information on this protocol go to: http://www.greenhousemag.com/FileUploads/image/GM1011_p72.jpg

Take Home Message:

Effective and safe chlorination can be achieve by (1) designing a system that decreases chlorine demand (filter before treatment and fertilize after treatment), (2) implementing cultural practices that increase efficacy (adjust pH to <7.0 and extend contact time), and (3) monitoring pH, ORP, active ingredient and microbial load.

Additional references:

1. Raudales, R, P Fisher, C Hall (2017) The cost of filtration. GPN Magazine-March 2017 http://www.gpnmag.com/wp-content/uploads/2017/04/GPNApril_WaterCost.pdf
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