Chlorine dioxide as a disinfectant for *Pythium aphanidermatum* in a closed loop irrigation system for greenhouse bell pepper

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ABSTRACT

Recirculating greenhouse irrigation is becoming a more common practice for vegetable growers in the US due to growing concern over freshwater shortages. Utilizing closed loop irrigation systems for greenhouse vegetable production not only saves the grower money due to reduced water and fertilizer use, it also reduces the amount of fertilizers being dispensed into the environment as spent irrigation. One drawback is that water-borne pathogens such as *Pythium, Phytophthora,* and *Fusariam* may proliferate in these irrigation systems. To prevent further spread of these pathogens, irrigation is disinfected using chemical sanitizers such as chlorine, chlorine dioxide, ozone, and hydrogen peroxide. Chlorine dioxide is advantageous over other widely-used chemical sanitizers because it is active over a wide pH range, it has a high oxidation capacity, and compared to chlorine it doesn't form carcinogenic halogenated compounds and is effective on organisms resistant to chlorine. Currently there is no recommendation for use of chlorine dioxide as a disinfectant in greenhouse vegetable production. To determine a rate recommendation for its use in a commercial setting, two laboratory experiments were conducted at the University of Florida in Spring 2011. In the first experiment, nutrient solution prepared according to University of Florida fertilizer recommendations for greenhouse bell pepper, pine bark media leachate, and perlite media leachate were treated with two concentrations of chlorine dioxide (10 and 20 ppm), and the concentration of residual sanitizer was measured over a four hour period. Deionized water and well water containing no fertilizer were also treated with chlorine dioxide as controls to determine fertilizer influence on chlorine dioxide residual. Treatments were arranged in a randomized complete block design, replicated three times, and repeated. Regression analysis was used to describe chlorine dioxide degradation in irrigation solution. These results are part of a larger set of experiments designed to develop a chlorine dioxide recommendation for sanitizing irrigation to prevent pathogen infection in closed loop systems in greenhouse bell pepper.

BACKGROUND

Chlorine dioxide has been well documented for its effectiveness as a sanitizer on a wide variety of plant pathogens (Table 1), however studies on sanitizing greenhouse irrigation solution with ClO_2 for vegetable production are limited. Irrigation in recirculating hydroponic systems will contain root exudates, media, and fertilizers and is expected to have a higher ClO_2 demand than fresh water. The oxidant demand of the water needs to be tested prior to ClO_2 application.

Figure 1. Peppers irrigated low concentrations of ClO_2 display minimal reduction of plant growth.

Pathogen	ClO_2 mg*L^{-1}	Treatment Time
Alternaria alternata [2]	25	1 min
Alternaria zinniae [1]	3	8 min
Botrytis cinerea [2,5]	3 - 25	1 - 60 min
Colletotricum capsici [1,4]	1 - 2	2-8 min
Cryptosporiopsis perennans [5]	3 - 5	1 min
Erwinia chrysanthemi [3,6]	5 - 20	20 - 60 min
Fusarium oxysporum [1,2,3,4,6]	1 - 25	4 - 60 min
Fusarium solani [6]	5	60 min
Mucor piriformis [5]	3 - 5	60 min
Penicillium corymbiferum [2]	25	60 min
Penicillium digitatum [6]	5	60 min
Penicillium expansum [5]	3 - 5	60 min
Phytophthora cinnamomi [1,4]	1 - 9	2 - 12 min
Pythium aphanidermatum [3,6]	1 - 5	20 - 60 min
Pythium irregulare [6]	5	60 min
Pythium ultimum [1]	2	4 min
Rhodococcus fascians [2]	25	60 min

Table 1. Suggested chlorine dioxide treatments for select plant pathogens. [x]References on bottom right.

MATERIALS AND METHODS

Chlorine dioxide (ICA Trinova, Newnan, GA) was added to five water samples and residual ClO_2 concentration was measured over a period of four hours. Water samples were adjusted to 6.0 pH and ClO_2 was added to achieve an initial concentration of 10 or 20 ppm. Treatments included two concentrations of chlorine dioxide (10 and 20) and five water samples (deionized water, well water, hydroponic nutrient solution, leachate from pine bark media, and leachate from perlite media), were each measured at five time points (0.25, 0.5, 1, 2, and 4 hours). Well water was collected from the Plant Sciences Research and Education Unit (PSREU) in Citra, Florida. Hydroponic nutrient solution was prepared using IFAS recommendations for greenhouse bell pepper production and prepared in PSREU well water. Leachate samples were collected from irrigation units shown in Figure 2.

The experiment was repeated four times over two days with two concurrent replications per day at the Nutrient Management Laboratory at the University of Florida. Data were analyzed (SAS,V.9.2 SAS Institute, Cary, N.C) using Proc Glimmix for repeated measures.

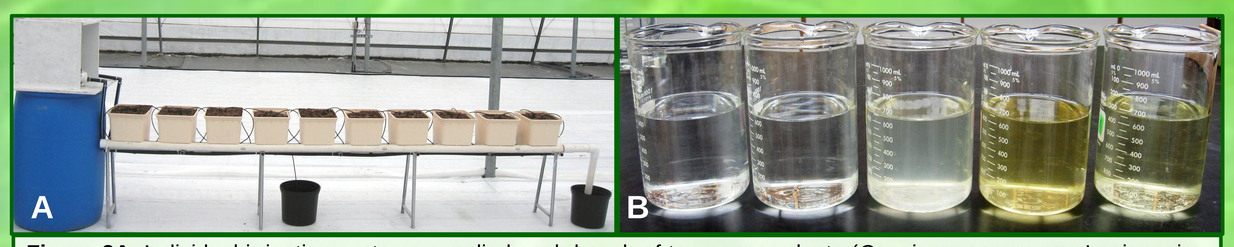
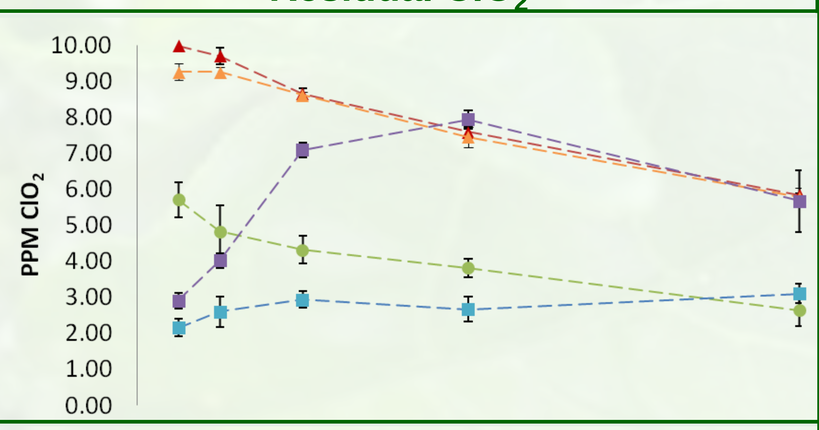
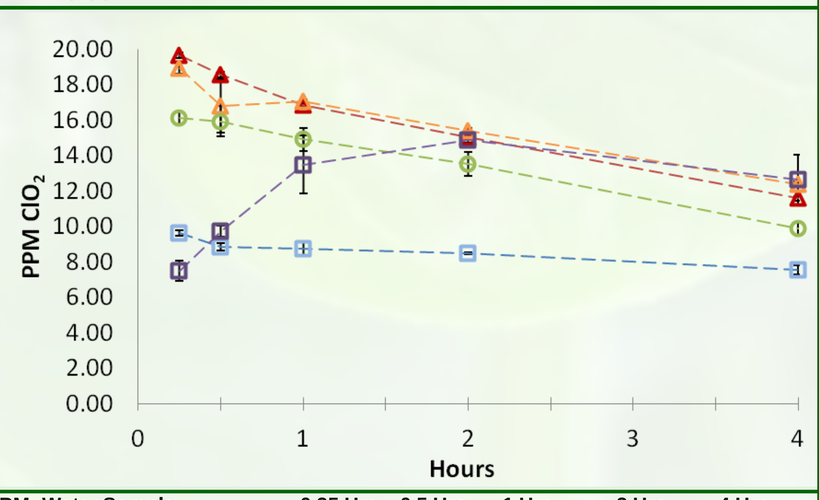


Figure 2A: Individual irrigation systems supplied each bench of ten pepper plants (*Capsicum annum*, var Legionnaire, Siegers Seed Co, Holland, MI). One soilless media (perlite or pine bark) was used at each bench. Individual plants were potted into 12.1 L Bato-bucket pots (General Hydroponics, Sebastopol, CA). At each bench, nutrient solution was stored in a 55 gal reservoir and supplied to plants through pressure compensating emitters (Flow: 2L/hr, Netafim, Tel-Aviv, Israel). Irrigation was maintained at a frequency to produce 20-30% leachate as recommended for greenhouse vegetables with recirculating irrigation. Leachate drained from individual pots into one shared five gal reservoir per bench. Eight weeks after transplant, leachate from perlite and pine bark benches was accumulated for one week and used in laboratory experiments. **Figure 2B**: Water samples from left to right: DI water, well water, nutrient solution, pine bark leachate, and perlite leachate.

RESULTS

Residual ClO_2





PPM	Water Sample	0.25 Hrs	0.5 Hrs	1 Hrs	2 Hrs	4 Hrs
10	DI water	10.0 c[x]A[y]	9.7 b A	8.7 c B	7.8 c C	5.8 d D
	Well Water	9.3 c A	9.3 b A	8.6 c A	7.5 c B	5.8 de C
	Nutrient Solution	5.7 e A	4.8 c AB	4.3 de AB	3.8 d BC	2.6 f C
	Pine Bark Leachate	2.2 f A	2.6 c A	2.9 e A	2.7 d A	3.1 ef A
	Perlite Leachate	2.9 f C	4.0 c BC	7.1 cd A	7.9 c A	5.7 de AB
20	DI water	19.6 a A	18.6 a B	16.9 a C	15.0 a D	11.6 ab E
	Well Water	18.9 a A	16.8 a AB	17.1 a AB	15.4 a BC	12.4 ab C
	Nutrient Solution	16.1 a A	15.9 a A	14.9 ab AB	13.5 b B	9.9 bc C
	Pine Bark Leachate	9.6 c A	8.8 b AB	8.8 c B	8.5 c B	7.5 cd C
	Perlite Leachate	7.5 d C	9.7 b BC	13.5 b AB	14.9 a A	12.6 a AB

[x]Mean separation in columns by Tukey's HSD test at a=0.05 (lowercase letters).

[y]Mean separation in rows by Tukey's HSD test at *a*= 0.05 (uppercase letters).

Residual ClO_2 was similar in **DI** and **Well** water for all time points and at both starting concentrations. Residuals remained high for the first half hour and steadily decreased by approximately 40% over four hours.

In the **Nutrient Solution**, the amount of ClO_2 demand was similar between treatment concentrations during the first two hours.

The 10 ppm treatment in **Pine Bark Leachate,** reached a minimum residual ClO_2 concentration at 2.5 ppm and remained constant over four hours. In 20 ppm, residual ClO_2 reduced to 9.6 ppm in the first 15 minutes then slightly decreased over four hours.

Residual ClO_2 in **Perlite Leachate** increased through hour two, then decreased. At each time point the percent ClO_2 remaining in solution was similar between treatment concentrations.

Residual ClO_2 differed between treatment concentrations of 10 and 20 ppm in all water samples at each time point (lowercase letters).

CONCLUSIONS

Residual ClO_2 concentrations in the hydroponic nutrient and leachate solutions dropped by 20% - 80% after 15 minutes and the ClO_2 demand from each water sample was dependant on treatment concentration. These results indicate that in a commercial setting ClO_2 demand should be examined over a range of concentrations to determine the minimum treatment dose that will create an optimal residual long enough to sanitize plant pathogens until mechanisms of ClO_2 demand are determined.

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