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SCREENING FOR CONTROL OF ALGAE IN COOLING PAD SYSTEMS

C. A. CONOVER, R. D. CALDWELL AND R. C. FLOHR[1]
Central Florida Research and Education Center
Institute of Food and Agricultural Sciences, University of Florida
2807 Binion Road, Apopka, FL 32703

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Abstract. **Twenty pad and fan cooling systems were set up with an east exposure in full sun in a field at the Central Florida Research and Education Center in Apopka to screen substances labeled for controlling algal growth. Each pad and fan system was connected to a 32-gallon container with 30 gallons of the solution being tested. The mixture was circulated during daylight hours and additional solution was added as needed to keep containers from running dry. Substances tested were: deep well water (check), sodium hypochlorite [Bleach] (15 and 30 ppm), bromine [Agribrom] (15 and 30 ppm), organo-sulfur [MBC-325] (1 and 2 oz/100 gallon), quaternary ammonium [WTB-28] (1 and 2 oz/100 gallon), MBC-325 + WTB-28 (1 oz each and 2 oz each/100 gallon), cupric sulfate (5 and 10 ppm), quaternary ammonium [Green Shield] (1 and 2 tsp/15 gallon), polymeric quaternary dichloride [MBC-130] (1 and 2 oz/100 gallon), ammonium chloride [R·D·20] (1 and 2 tsp/15 gallon) and ammonium chloride [Prevent] (2 oz/100 gallon). Fans and pads were operated from 28 June through 16 Oct. 1993 and from 16 May through 26 Sept. 1994. Results indicated that the use of sodium hypochlorite or bromine at the rates tested was no better than using water with no additives. In 1993 no algal growth was seen on the pads with WTB-28 at the high rate or on pads with the combination MBC-325 + WTB-28 at either the low or high rate during the 16-week experiment, and in 1994 no algae was detected on these pads until 10, 9 and19 weeks into the 19-week experiment, respectively. No concurrent replications were done.**

All greenhouse crops have an optimum temperature range and any prolonged period of time outside of the optimum range, or even short periods of time at extreme temperatures, can have detrimental effects on crops. A method commonly used to ensure that greenhouse temperatures do not stay too warm for any extended period is the fan and pad cooling system (Nelson, 1978). This system is based on the principle that evaporation of water requires heat absorption. In a working system, fans at one end of a greenhouse pull air through water-saturated pads located at the opposite end of the greenhouse. As warm air passes through the pad airways, water on the pads absorbs heat from the air and evaporates, and the air is cooled. Obstruction to air passage through the pads can decrease cooling efficiency of the system, which, in Florida, is already limited by high relative humidity during much of the year. Therefore, pad airways must be kept as clear as possible for best cooling efficiency. One problem impeding the success of fan and pad cooling is growth of algae on the pads which obstructs air passage through the airways. In an attempt to find a method of maintaining relatively algae-free pads, an experiment was set up at the Central Florida Research and Education Center in Apopka to test the efficacy of several chemicals in controlling algal growth on evaporative pads.

Materials and Methods

Twenty pad and fan cooling systems were constructed and set up with an east exposure in full sun in a field at the Central Florida Research and Education Center in Apopka. Each pad and fan system consisted of a 48-inch high x 24.5-inch wide pad and a single fan that created an air flow of 1 cubic foot per minute, the normal greenhouse engineering standard. Each system was connected to its own 32-gallon container with 30 gallons of the solution being tested. Fans were operated and mixtures circulated from 7:00 am to 7:00 pm daily and additional solution was added as needed to keep reservoirs from running dry. Substances tested were: water (check), Bleach [sodium hypochlorite] (15 and 30 ppm), Agribrom® [1-bromo-3-chloro-5,5-dimethyl-2,4-imidazolidinedione] (15 and 30 ppm), MBC-325 [potassium dimethyldithiocarbamate] (1 and 2 oz/100 gallon), BioGuard® WTB-28™ [alkyl dimethyl benzylammonium chloride] (1 and 2 oz/100 gallon), MBC-325 + WTB-28 (1 oz each and 2 oz each/100 gallon), cupric sulfate [$CuSO_4 + 5H_2O$)] (5 and 10 ppm), Whitmire PT® 2000 Green Shield [n-Alkyl dimethyl benzyl ammonium chloride, n-Alkyl dimethyl ethylbenzyl ammonium chloride] (1 and 2 tsp/15 gallon), MBC-130 [poly(oxyethylene[dimetyliminio] ethylene [dimetyliminio] ethylene dichloride)] (1 and 2 oz/100 gallon), R·D·20® [ammonium chloride] (1 and 2 tsp/15 gallon) and Prevent [alkyl dimethyl benzyl ammonium chloride; octyl decyl dimethyl ammonium chloride] (2 oz/100 gallon). Types of compounds and manufacturers' names are listed in Table 1. The low rate of each chemical tested is the manufacturer's recommended rate (if applicable).

The 20 units were operated from 28 June through 16 Oct. 1993 and, with new pads, from 16 May through 26 Sept. 1994. Each pad was rated weekly for the presence of algae. The following rating system was used: 0 = no algae; 1 = initial appearance of algae; 2 = algae spreading on the pad, but not bad; 3 = algae growing rapidly on the pad and covering about half of it; 4 = heavy growth of algae, covering much of the pad; and 5 = very bad appearance, pad covered with thick algae. Grades after first appearance were based on a combination of the area of the pad with algae present and relative density of the algal growth. At experiment termination in 1993, algae samples were collected from the recommended (lower) rate treatments and the control. All samples were divided and half were placed in vials containing de-ionized water and the other half were placed in vials containing the treatment solutions running through the pad from which the algal sample was collected. All samples were sent to Dr. Edward P. Lincoln, Ag-

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[1]Professor of Environmental Horticulture and Center Director, Biological Scientist and Research Gardener, respectively.

Table 1. Types of compounds and manufacturers of substances tested for the control of algae on evaporative cooling pads during two experiments run from 28 June to 16 Oct. 1993 and 16 May to 26 Sept. 1994 at the Central Florida Research and Education Center in Apopka.

Test substance	Type of compound	Manufacturer
Kem Tek Bleach	liquid chlorinating	Chem Lab Products, Inc., Ocala, FL
Agribrom	halogenated hetrocyclic (bromine, chlorine)	Great Lakes Chemical Corporation, West Lafayette, IN
MBC-325	organo-sulfur	Bio-Source, Snellville, GA
WTB-28	quaternary ammonium	Bio-Source, Snellville, GA
Cupric Sulfate ($CuSO_4 \cdot 5H_2O$)	copper sulfate	Fisher Scientific Company, Fair Lawn, NJ
Green Shield	quaternary ammonium chloride	Whitmire Research Laboratories, Inc., St. Louis, MO
MBC-130	polymeric quaternary-based microbiocide	Bio-Source, Snellville, GA
R·D·20	ammonium chloride	R. D. & Associates, Inc., Pomona, CA
Prevent	ammonium chloride	The Buffalo Co., Charlotte, NC

ricultural Engineering Department, UF, Gainesville for microscopic analysis.

Results and Discussion

In 1993, the first appearance of algae on four of the pads occurred by the second week of operation (Table 2). These four pads—the water check, bleach at both rates, and Agribrom at the 15 ppm rate—continued to allow algal growth throughout the test. The following week algae was noted on the pad with Agribrom at the high (30 ppm) rate. These five pads had virtually the same algal coverage rating (4.5 to 5.0) at the end of the 16-week test. Three chemical treatments, WTB-28 at the high rate (2 oz/100 gal) and the MBC-325 + WTB-28 combination at both rates (1 or 2 oz of each/100 gal), prevented algal growth on their pads throughout this experiment. Algal growth on pads with all other treatments appeared in 5 to 10 weeks and algal ratings ranged from 1.5 to 4.0 at the end of the test. Algal growth/coverage on pads of some treatments—MBC-325 (1 oz/100 gal), cupric sulfate (10 ppm) and MBC-130 (2 oz/100 gal)—seemed to be declining at the end of the 16-week period. One treatment (MBC-130; high rate) provided an environment in which an unidentified, but not obstructive, orange-colored growth thrived on the pad.

In 1994, first appearance of algae on the pads did not occur until during the third week of the test, however, six of the treatments exhibited algal growth at that time. Besides the four which showed algal growth the earliest in 1993 (water, both Bleach rates, and Agribrom at 15 ppm), the pads with cupric sulfate at the 10 ppm rate and R·D·20 at the 1 tsp/15 gal rate had algal growth by the third week of this test. With the exception of the cupric sulfate at 10 ppm pad (rating of 3.0), these pads and the pad with Agribrom at the high rate ended the experiment with a 5.0 for algal grade. The low rate MBC-325 + WTB-28 combination pad and the pad with the high rate of WTB-28, both of which showed no algae in 1993, were observed to have algae upon inspection during weeks 9 and 10, respectively, in this second test. The pad with the MBC-325 + WTB-28 combination at the high rate (2 oz each/100 gal) resisted algal growth, and first appearance of algae (grade 1.0) was detected only at the final inspection of the pads at experiment termination. The remaining thirteen

Table 2. Number of weeks before first appearance of algae on evaporative cooling pads with various algicide treatments in 1993 and 1994, and algae grade[z] and number of weeks at that grade at termination of each experiment.

		Weeks until first algal appearance		Final algae grade (number of weeks at final grade)			
Algicide treatment	Application rate	1993 (16 wk)	1994 (19 wk)	1993		1994	
CHECK	N/A	2	3	4.75	(4)	5.0	(6)
Bleach - 5.25% by wt	15 ppm	2	3	5.0	(4)	5.0	(6)
Bleach - 5.25% by wt	30 ppm	2	3	5.0	(5)	5.0	(6)
Agribrom	15 ppm (bromine)	2	3	5.0	(6)	5.0	(2)
Agribrom	30 ppm (bromine)	3	5	4.5	(2)	5.0	(6)
MBC-325	1 oz/100 gal	5	5	2.25	(1)*	4.0	(1)
MBC-325	2 oz/100 gal	10	7	2.75	(1)	3.0	(1)*
WTB-28	1 oz/100 gal	7	7	2.5	(1)	2.75	(1)
WTB-28	2 oz/100 gal	no algae	10	0		2.75	(1)
MBC-325 + WTB-28	1 oz + 1 oz/100 gal	no algae	9	0		2.25	(1)
MBC-325 + WTB-28	2 oz + 2 oz/100 gal	no algae	19	0		1.0	(1)
Cupric Sulfate ($CuSO_4 \cdot 5H_2O$)	5 ppm	7	5	3.75	(1)	4.0	(1)*
Cupric Sulfate ($CuSO_4 \cdot 5H_2O$)	10 ppm	7	3	4.0	(2)*	3.0	(1)*
Green Shield	1 teaspoon/15 gal	5	5	3.75	(1)	4.0	(1)
Green Shield	2 teaspoons/15 gal	7	9	2.0	(7)	2.25	(1)
MBC-130	1 oz/100 gal	8	7	1.5	(5)	2.0	(1)*
MBC-130	2 oz/100 gal	8	5	1.5	(2)*	2.0	(1)*
R·D·20	1 teaspoon/15 gal	8	3	2.25	(1)	5.0	(3)
R·D·20	2 teaspoons/15 gal	7	7	1.75	(2)	2.5	(1)
Prevent	2 oz/100 gal	4	5	3.25	(1)	4.75	(3)

[z]Grades based on 0 = no algae; 1 = first appearance of algae; 2 = algae spreading on the pad, but not bad; 3 = algae growing rapidly on the pad and covering about half of it; 4 = heavy growth of algae, covering much of the pad; and 5 = very bad appearance, pad covered with thick algae.
*Grade had been higher in previous week(s) but had been this lower grade for (x) weeks at experiment termination.

pads had algal ratings ranging between 2.0 and 4.75, all higher than in 1993, with only the pad treated with cupric sulfate at the high rate exhibiting less algal growth in 1994 than 1993. In 1994, more rain fell and skies were more overcast than in 1993 and this may have accounted for the higher algal growth rating for the various treatments.

All samples sent to Gainesville, except the one from the MBC-130 pad sent in the actual treatment solution, contained live algae; Oocystis was present to varying degrees in all of them and was the only alga present in some samples. Also predominant were: *Anabaena* spp., *Chlamydomonas* spp., and *Chlorella* sp. Organisms that were present at trace levels included: *Anabaenopsis* spp., *Ankistrodesmus* sp., *Oscillatoria, Phormidium, Synechococcus* sp., *Chloroflexus* sp. (a photosynthetic bacterium), *Mastigophora* sp. (a protozoan), Pennate diatoms, rotifers (including *Brachionus rubens*), *Euglena*, some *Chlorella*-form cells and some other ciliates.

Conclusions

Although all ratings were subjective, results indicated that there are some chemicals available which could deter algal growth on evaporative cooling pads when used at the recommended rate. The most effective of the compounds tested during these two years was the combination of MBC-325 + WTB-28 (2 oz each/100 gal). In the first test this combination at both rates prevented algal growth and in 1994 the high rate combination provided excellent control of algal growth while the algal growth rating of the pad with the low rate combination was still below a grade of 3.0, indicating good control of algal growth. Additionally, algal growth control by MBC-130 was the same at either rate for each year and only the high rate combination treatment gave better algal control in 1994. Other substances tested that gave good control (3.0 rating or less) for both years were both rates of WTB-28 when used alone and the high rates of MBC-325, Green Shield and R·D·20.

This trial information supports the hypothesis that there are algicides available which can be circulated through the pads in evaporative cooling pad and fan systems to effectively impede the growth of algae on the pads. This will, in turn, allow more efficient cooling of greenhouses. More research is warranted and should include the effects on the pads, if any, of using these chemicals over extended periods.

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INTERMITTENT IRRIGATION FOR COLD PROTECTION CONSERVES WATER IN ICED SHADEHOUSES DURING RADIATION FREEZES

ROBERT H. STAMPS
Central Florida Research and Education Center
Institute of Food and Agricultural Sciences, University of Florida
2807 Binion Road, Apopka, FL 32703-8504

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Abstract. **Over-the-shadehouse (OS) and over-the-crop (OC) irrigation systems were operated intermittently during radiation freezes to cold protect leatherleaf fern [*Rumohra adiantiformis* (Forst.) Ching]. The shadehouse was covered with shade fabric designed to reduce incoming radiation by 70% and sidewalls were also covered with polyethylene film. Temperatures inside and outside the shadehouse were monitored using type T thermocouples. During a January freeze, average hourly temperatures outside the shadehouse remained below 0°C [32°F] for 13 hours and reached a low of -3.5°C [25.7°F]. Using a wet-bulb temperature setpoint of 1.1°C [34°F] (measured inside the fernery) to turn the irrigation systems on and off, the duration of continuous irrigation for cold protection was 4 hours. However, actual OS and OC irrigation systems run-times were 7 and 47 minutes, respectively. During a February freeze with similar low temperatures, average hourly temperatures outside the shadehouse remained below freezing for 9.5 hours and wet-bulb temperatures inside remained at or below the set-point for 8 hours. OS and OC irrigation systems run-times were 35 and 52 minutes during this freeze, respectively. No damage occurred to the crop during either freeze and irrigation run-times and water volumes applied were reduced by about 80% compared to irrigating continuously during both freezes.**

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Irrigation water has been used successfully for frost protection in the United States for over 70 years (Businger, 1965); however, it was not until the 1960s that this technique became widely used for cold protection in Florida and elsewhere throughout the U.S. (Harrison et al., 1975). Using water for cold protection can be an economical and easily implemented method in situations where it is acceptable to use overhead irrigation systems (Stamps and Haman, 1991). Once water is applied, it has been recommended that water continue to be applied more or less continuously (Businger, 1965; Harrison and Conover, 1970). In fact, an interruption of water application may result in cold damage greater than that if water were not applied at all (Rosenberg et al., 1991). Liquid water must be available at all times since it is the heat liberated when water freezes into ice that is the major source of energy to prevent cold damage (Harrison et al., 1975). Besides the above mentioned increased risk of crop damage, there are other potential disadvantages of using water for cold protection—including leaching of nutrients and pesticides, drawdowns of aquifers, and saturation of the root zone enhancing disease development. Therefore, successful cold protection of shadehouse-grown crops using intermittent wa-