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ALGAE CONTROL IN AN EBB AND FLOW IRRIGATION SYSTEM

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Abstract. **Good to excellent algae control in our ebb and flow irrigation was achieved with 2 ppm copper ($CuSO_4$), 30 ppm chlorine (Clorox™), or 0.5 oz of MBC-325 (organo-sulfur)/gal. No phytotoxicity was encountered with the products or rates tested with the exception of the 3 ppm of copper. Bromine (Agribrom™) did not give good algae control in our ebb and flow irrigation system. The degree of algae control differed according to time of year since light and temperature affected degree of algae growth in this system. Some chemicals such as WTB-28 (quaternary ammonium) performed adequately when algae growth was slow to moderate but failed when algae growth was rapid.**

One severe problem faced by southern ornamental growers is algae that grow on pots, media or soil, benches, walkways, and plants (McCain and Sciaroni, 1965). The high humidities, rainfall, light intensities and temperatures so common to the southeastern United States are ideal for algae growth (Powell, 1986). When this environment is coupled with high nutrient levels used in ornamental production, algae growth explodes. Algae also have become problematic in ebb and flow irrigation systems which are becoming more common throughout the southeastern U.S. since abundant water and fertilizer are always available for their growth. While considerations such as plant quality and disease spread are important whenever these systems are employed, the threat of algae is not viewed as a concern elsewhere in the country. Algae are a special problem in ebb and flow irrigation systems.

Methods used to control algae differ depending upon the surfaces where they grow (Powell and Shumard, 1984). Walkways, pots and benches can be treated with chemicals which may be toxic to plants (Chase and Osborne, 1984). Sodium hypochlorite (commercial bleach), bromine (Agribrom™), copper, and quaternary ammonium compounds are available for algae control on nonliving surfaces. In addition, algae control in cooling pads is generally achieved with chemicals, especially the quaternary ammonium compounds.

Most algae control products are not recommended for direct application to plants since they can be toxic. Although commercial bleach (5.25% sodium hypochlorite diluted 1:10 with water) provides good short-term control of algae on the soil surface, regrowth occurs within 3 days (Chase and Osborne, 1984).

Agribrom™ is another effective product for controlling algae on surfaces and plants without producing phytotoxic effects. Agribrom™ injected into the mist system at 10 to 30 ppm is recommended to control algae growth during plug production (Rickard and Tayama, 1990). Agribrom™ (25 ppm bromine) has also proven efficacy in controlling algae without causing damage to many bedding plants and most foliage plants (Chase, 1990).

Need for safe nontoxic algae control treatments for use in closed watering systems such as ebb and flow is increasing as more U.S. growers install these systems. The following research was conducted to better evaluate some of the chemicals which are currently used to control algae and other microorganisms in greenhouses, on evaporative cooling pads and in cooling tower systems.

Materials and Methods

Exp. 1 - Safety and efficacy of bromine, chlorine and copper. The first test was initiated on 12 June 1990 using eight species of ornamental plants: *Chamaedorea elegans* Mart. (parlor palm), *Codiaeum variegatum* (L.) Blume 'Gold Dust' (croton), *Dieffenbachia maculata* (Lodd.) G. Don 'Camille', *Ficus benjamina* L. (weeping fig), *Philodendron scandens* C. Koch & H. Sello subsp. *oxycardium* (heartleaf philodendron), *Schefflera arboricola* H. Ayata (dwarf schefflera), *Spathiphyllum* L. sp. 'Petite', and *Syngonium podophyllum* 'White Butterfly' (nephthytis). Plants growing in 6-inch pots containing Fafard Growing Mix #4 were placed in ebb and flow watering systems, with four replications per treatment. The ebb and flow irrigation system has been described (Poole and Conover, 1992). The systems were located in a greenhouse where maximum light intensity was 2600 ft-c and air temperatures ranged from 70 to 95°F. Irrigation solutions in the ebb and flow systems contained 200 ppm N from 24N-3.5P-13.3K (Peters 24-8-16 soluble fertilizer at the rate of 0.7 oz/100 gal). Nutrients were added weekly by refilling the irrigation water in the tanks with water containing fertilizer at the rate given. From 12 June until 25 July 1990, ebb and flow irrigation solutions contained one of the following amendments: 15 ppm bromine (Agribrom™ from Great Lakes Chemical Corporation, West Lafayette, IN), 15 ppm sodium hypochlorite (Clorox™), or 1 ppm copper ($CuSO_4$). These compounds were added weekly to the irrigation solutions by amending the new water only. A control treatment was included for comparison. Height and plant grade (1 = dead, 2 = poor quality, unsalable, 3 = fair quality, salable, 4 = good quality and 5 = excellent quality plants) were determined on 29 July 1990 after 6 weeks growth.

On 25 July 1990, rates of algae control chemicals in irrigation solutions were doubled and on 25 Sep. 1990 plants were graded again using the scale described above. Algae growth was evaluated on the following scale: 1 = none, white bench, 2 = slight green growth, 3 = moderate green growth, 4 = high green growth, and 5 = complete green surface.

Exp. 2 - Safety and efficacy of copper. A second test was initiated on 31 Oct. 1990 using 'Camille' dieffenbachia, 'Gold Dust' croton, parlor palm, 'Petite' spathiphyllum and 'White Butterfly' nephthytis, as described in Exp. 1 using six replications per treatment. Maximum light intensity

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was 1200 ft-c and air temperatures ranged from 65 to 90°F. Irrigation water contained 200 ppm N from 24N-3.5P-13.3K soluble fertilizer as described in Exp. 1. Algae treatments were 0, 1, 2 or 3 ppm copper ($CuSO_4$). Plant quality and height were recorded on 1 Mar. 1991 using the scale previously described.

Exp. 3 - Efficacy and safety of MBC-325, MBC-130 and WTB-28. The first two tests were conducted using 'Camille' dieffenbachia to determine the ability of MBC-325 (potassium dimethyldithiocarbamate, an organo-sulfur compound from Bio-Source, Snellville, GA 30278), MBC-130 (poly[oxyethylene(dimetyliminio) ethylene (dimetyliminio) ethylene dichloride], a polymeric quaternary based microbiocide from Bio-Source) and WTB-28 (alkyl dimethyl benzyl ammonium chloride, a quaternary ammonium compound from Bio-Source) to keep algae growth from occurring in a clean ebb and flow irrigation system. Algicides were added to make up irrigation water weekly at the rate of 0.5 oz of each product per 100 gallons of irrigation water. Four replications per treatment were used. Plants were treated as described in Exp. 1. The first test was conducted from 30 Sep. to 28 Oct. 1992 when algae growth was rated as described above and plant grade was determined as in Exp. 1. Maximum light intensity was 2000 ft-c and air temperatures ranged from 70 to 95°F. The second test was similar but was conducted from 12 Nov. 1992 to 4 Feb. 1993. Maximum light intensity was 1500 ft-c and air temperatures ranged from 60 to 90°F. Algae growth was rated four times during the second test.

Exp. 4 - Efficacy and safety of MBC-325 and WTB-28 alone and in combination. Treatments included WTB-28 and MBC-325 each at 0.5 oz/100 gal as well as a combination treatment using 0.5 oz/100 gal of each algicide. Two tests were conducted to evaluate the ability of the compounds to control a standing algae growth. Eight foliage plants were grown for about 3 months using the methods described in Exp. 1: *Brassaia actinophylla* Endl. (schefflera), *Dieffenbachia* Schott 'Triumph', *Epipremnum aureum* (Linden & Andre) Bunt. 'Marble Queen' (pothos), *Ficus benjamina* L. 'Exotica', *Hedera helix* L. 'Hahn', *Maranta leuconeura* E. Morr. var. *erythroneura* Bunting (red maranta), 'Petite' spathiphyllum, and *Syngonium podophyllum* Schott 'Monet'. Two plants of each type were placed in each tray to give four replications per algicide treatment. Algae grade was rated just prior to starting the algicide treatments and then again about 3 to 4 weeks later. The first test was conducted from 12 Mar. to 24 June 1993 with maximum light intensity of 2500 ft-c and air temperatures ranging from 60 to 90°F. The second test was conducted from 16 July to 18 Oct. 1993 with maximum light intensity of 3500 ft-c and air temperatures ranging from 70 to 95°F.

Exp. 5 - Safety of MBC-325, MBC-130 and WTB-28 on foliage plants. Four foliage plants were sprayed to drip with MBC-325, MBC-130, WTB-28 or water. Algicides were applied at the rate of 1.0 oz/100 gal on 27 July and 3 Aug. 1992. The plants employed were *Aechmea fasciata* (Lindl.) Bak. (urn plant, bromeliad), *Nephrolepis exaltata* (L.) Schott 'Compacta' (Boston fern), 'Petite' spathiphyllum, and schefflera. Five plants were used for each treatment arranged in a randomized complete block design and were grown with maximum light intensity of 3500 ft-c and air temperatures ranging from 70 to 95°F.

Table 1. Algae grade and plant grades of three foliage plants grown in an ebb and flow irrigation system with algae control products included in irrigation water. Plants were grown from 12 June until 29 Sep. 1990[z].

Chemical (rate)	Algae grade[x]	Plant grade[y]		
		Dieffenbachia maculata 'Camille'	*Ficus benjamina*	*Schefflera arboricola*
Bromine (30 ppm)	4	5.0a[w]	5.0a	5.0a
Chlorine (30ppm)	1	4.7a	5.0a	5.7ab
Copper (2 ppm)	2	4.2b	4.2b	4.2b
Control	3	5.0a	5.0a	5.0a

[z]Plants were grown from 12 June until 25 July 1990 with 15 ppm bromine (Agribrom™), 15 ppm chlorine (Clorox™), 1 ppm copper ($CuSO_4$) or no treatment. The rates of chemical were doubled on 25 July and plants were grown on until experiment termination on 29 Sep. 1990.
[y]Plants were graded on a scale of 1 = dead, 2 = poor quality, unsalable, 3 = fair quality, salable, 4 = good quality and 5 = excellent quality.
[x]Algae growth was rated on the following scale: 1 = none, white bench, 2 = slight green growth, 3 = moderate green growth, 4 = high green growth, and 5 = complete green surface.
[w]Mean separation in columns by Duncan's multiple range test, 5% level.

Results and Discussion

Exp. 1 - Safety and efficacy of bromine, chlorine and copper. No differences were found when comparing growth of individual species with any of the chemicals used in the ebb and flow systems. All plants sustained a normal rate of growth and none showed symptoms of phytotoxicity due to treatment. The sodium hypochlorite and copper treatments were slightly more effective in retarding algae build up but, unfortunately, algae growth was not satisfactorily controlled in any of the systems (results not shown).

The height of all species, and plant grades of five, were unaffected by treatment at the end of the test following exposure to double the original rates. Plant grade of the three species influenced by treatment show similar effects (Table 1). 'Camille' dieffenbachia, weeping fig and dwarf schefflera grown in systems where irrigation water contained 2 ppm copper had lower plant grades than plants grown in the three other systems. However, all plants in this test were judged to be of salable or greater quality when experiment was terminated. Algae control was adequate with 30 ppm sodium hypochlorite or 2 ppm copper in irrigation water but was poor when 30 ppm bromine was used (Table 1).

Exp. 2 - Safety and efficacy of copper. Height increase of all foliage plants except 'Camille' diffenbachia was unaffected by copper treatments. 'Camille' dieffenbachia grew less in ebb and flow systems with irrigation water containing 3 ppm copper (Table 2). However, 'Camille' dieffenbachia response to treatment was quadratic, with greatest height increases from plants in watering systems containing 2 ppm copper. Little algae growth occurred in this test, probably due to the time of year since this experiment was conducted in the winter when algae growth is slower.

Exp. 3 - Efficacy and safety of MBC-325, MBC-130 and WTB-28. Additional tests with these algicides which are

Table 2. Height increase of *Dieffenbachia maculata* 'Camille' as affected by rate of copper used in an ebb and flow irrigation system. Plants were grown from 31 Oct. 1990 until 1 Mar. 1991.

ppm copper	Initial height (inches)	Height increase (inches)
0	6.8	5.8
1	7.0	6.0
2	7.6	6.8
3	6.9	5.3
Significance[z]		
linear	ns	ns
quadratic	ns	**

[z]ns, **, Results nonsignificant or significant at P = 0.01, respectively.

labeled for use in cooling pads showed that some could give excellent control of algae without damaging foliage plants produced with treated irrigation water. Algae control in the first test was best with WTB-28 at 1.8 followed by MBC-325 at 2.0, the control at 3.5 and the MBC-130 at 4.0. These ratings indicate a relatively high degree of algae growth during the test period. No damage to any plants was noted in this test.

In the second test, algae control was best with MBC-325 although MBC-130 also gave good control for the majority of the test (Table 3). WTB-28 did not give good algae control although overall algae growth was relatively low during this winter test with a high rating of only 2.5. No damage to any plants was noted in this test.

Exp. 4 - Efficacy and safety of MBC-325 and WTB-28 alone and in combination. These tests showed good reduction of a standing algae growth with MBC-325 only (Table 4). WTB-28 did not reduce algae growth in the second test and even allowed further algae growth to occur. The combination of WTB-28 and MBC-325 gave good reduction of the algae growth in the first test but did not give good control in the second test. It seems apparent that the degree of control achieved with these products is related to the amount of standing algae growth present when they are applied as well as the environmental conditions which affect the rate of algae growth. No damage to any plants was noted in these tests.

Exp. 5 - Safety of MBC-325, MBC-130 and WTB-28 on foliage plants. Direct application of these products to foliage plants did not cause noticeable damage to the plants tested (results not shown).

These tests indicate that a number of compounds can be used safely and effectively to control algae growth in ebb and flow systems used to produce foliage plants. When plants other than those tested here are being produced, phytotoxicity of a new algicide employed should be evaluated prior to broadscale use of the product.

Table 3. Efficacy of MBC-325, MBC-130 and WTB-28 for algae control in an ebb and flow irrigation system.

	Average algae grade[z] (date)			
Treatment[y]	24 Nov. 92	11 Dec. 92	4 Jan. 93	4 Feb. 93
MBC-325	1.0	1.0	1.0	1.0
MBC-130	1.0	1.1	1.2	2.0
WTB-28	1.2	2.1	1.8	2.5
Control	1.8	2.0	1.6	2.3

[z]Algae grade was estimated periodically during the test and the following scale was used: 1 =none, white bench, 2 = slight green growth, 3 = moderate green growth, 4 = high green growth, and 5 = complete green surface.
[y]Algicides were added to make up irrigation water weekly at the rate of 0.5 oz of each product per 100 gallons of irrigation water.

Table 4. Efficacy of MBC-325 and WTB-28 alone and in combination for algae control in an ebb and flow irrigation system.

	Average change in algae grade[z]	
Treatment[y]	Test 1 pre-treatment to post-treatment 28 May to 24 June 93	Test 2 pre-treatment to post-treatment 29 Sep. to 18 Oct. 93
WTB-28	2.6 to 2.1	2.5 to 3.4
MBC-325	2.4 to 2.0	2.9 to 1.9
WTB-28 and MBC-325	2.6 to 1.4	2.9 to 3.1
Control	2.5 to 3.6	2.4 to 3.4

[z]Algae grade was estimated prior to use of any algicide for four trays and again after algicide treatments were initiated. The following scale was used: 1 = none, white bench, 2 = slight green growth, 3 = moderate green growth, 4 = high green growth, and 5 = complete green surface.
[y]Algicides were added to make up irrigation water weekly at the rate of 0.5 oz of each product per 100 gallons of irrigation water.

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