stock. In approximately 3 months the graft has healed and roots have formed on the rootstock. This then gives us trees which should react in a uniform manner when used in commercial plantings.

I want to compliment Don and Floyd Dillon and Fred Real on their papers covering twig grafting and given to this Society earlier. Anyone interested in this should certainly read their works. They give great descriptions on method, cleanliness, and facilities. Floyd, in his paper, gives full credit to Dr. Halma and Ted Frolich for their generous contribution to those of us who are working in propagation. It was my experience, too, that these two men were always ready to help us when we went to them with questions.

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USE OF MONOCHLORAMINE AS A DISINFECTANT FOR PRUNING SHEARS

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Abstract. Chloramines were investigated for use in disinfection of pruning shears and their efficacy compared with Physan, isopropyl alcohol, propylene glycol, 8-hydroxyquinoline sulfate, and combinations of propylene glycol and terramycin and streptomycin. The objective was to find a suitable replacement for isopropyl alcohol which would have equal or better efficacy, good stability under high contamination, and lower cost Phytotoxicity and corrosiveness of several disinfectants were also investigated.

The best disinfectants were found to be Physan, isopropyl alcohol, and monochloramine Of these, monochloramine was found to be equal in efficacy to the alcohol, least corrosive, least costly, and had excellent stability under high contamination

INTRODUCTION

Monrovia Nursery normally shears the long roots of rooted cuttings to facilitate handling during potting. Since shearing

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cuts through roots, this can be a source of contamination and inoculation unless some provision is made to disinfect the pruning shears. In the search for a disinfectant we were looking for a stable product which will provide disinfection under high organic contamination. Many disinfectants such as sodium hypochlorite (Clorox) and the quaternary ammonium compounds react with organic matter and are quickly inactivated. For a number of years we used 70% isopropyl alcohol which retains its disinfection qualities under high organic contamination. However, with the costs of alcohol increasing, we found that during the peak potting period, we might use $230 worth of isopropyl alcohol per month. Consequently, we embarked on seeking and testing a number of disinfectants for their efficacy and stability. The culmination of these tests resulted in the use of monochloramine.

Although chloramines have been known since 1890 and were first used in water treatment in Canada in 1917 and used in a number of cities in the late 1920s in the United States, it is relatively unknown by the general public (1). A search of biological and horticultural journals reveals no information on the use of chloramines as disinfectants in horticulture. Jefferson Parish, Louisiana, has used monochloramine as the sole disinfectant for drinking water for over 30 years (Montgomery, James M., Consulting Engineers, Inc. 1981. Alternative Disinfectants for Trihalomethane Control: A Report to MWD, Dec: 2-36, unpublished). The city of Denver, Colorado, has used chloramines for water disinfection for over 70 years (1). The city of San Diego has converted from chlorination to chloramination as recently as 1982. The Metropolitan Water District of Southern California (MWD) converted to chloramination November 1, 1984 (personal communication with the MWD, May 31, 1984). The purpose of this change was to reduce the production of trihalomethanes, which are suspected carcinogens. Trihalomethanes are produced when chlorine reacts with trace organics in water supplies. Monrovia Nursery has been chloraminating its recycled water since the treatment plant's inception in 1979. MWD will be using monochloramine, because it does not have the typical chlorine taste or odor, and is more acceptable than chlorination of water.

Chloramine is the general term for any of the three forms: monochloramine, dichloramine, and trichloramine. Monochloramine (NH_2Cl) forms when chlorine reacts with ammonia in a Cl:N ratio of 5:1 or less. When the ratio of Cl:N is greater than 5:1, dichloramines and trichloramines begin to form.

MATERIALS AND METHODS

Two methods of evaluating the bacteriacidal qualities of monochloramine were used: a) artificial inoculation of monochloramine solutions with a portion of old propagation medium, and b) actual field use of the disinfectant for dipping pruning shears. Samples of the solutions were withdrawn at different intervals of time and inoculated on nutrient agar in petri dishes by dipping an L-shaped glass rod into the sample and smearing the unfiltered, undiluted solution over the surface of the agar. The petri dishes were then placed in an incubator at 27°C (81°C) or 30°C (86°F) for periods of 24 to 96 hours. Individual colonies of bacteria were counted at the end of each incubation period.

For artificial inoculation, 20 cc of spent propagation medium (8 perlite:1 peat) was macerated in a blender with 250 cc of tap water. The suspension was added to a 1 liter volumetric flask, ammonium sulfate added, dissolved; followed by the addition of sodium hypochlorite solution and water to bring to volume. This resulted in a heavily contaminated sample having a turbidity of 85 ntu. Samples were withdrawn at intervals of time and transferred to nutrient agar in petri dishes. The inoculated dishes were then incubated.

For evaluation under actual field conditions, several concentrations of the disinfectants were made up, and poured into containers for dipping pruning shears. The solutions were not changed during the entire day. This resulted in "zero" contamination initially with the solutions gradually increasing in contamination as the day progressed. This is in contrast to the artificial inoculation where the solution was highly contaminated initially. The artificial inoculation delineates the efficacy of the product as a bacteriacide based on the longevity of exposure of the organisms to the disinfectant. The field evaluation, in contrast, has continuous re-inoculation every time the shears are dipped.

The corrosiveness of some of the solutions was tested by partially immersing a 7.6 cm (3 in.) × 2.5 cm (1 in.) piece of sanded degreased, cold-rolled steel bar. After 192 hours, the bars were removed and observed for pitting and corrosion.

The phytotoxicity of the solutions were tested by spraying the disinfectant on the bare roots and the tops of tomato plants grown in pots. Another test evaluated 340 and 680 mgl^{-1}(ppm) monochloramine sprayed on bare roots of five different ornamentals. The solutions were sprayed to wet the surfaces of all roots surrounding a 2832 cc (1 gal.) container root ball. Observations for phytotoxicity were made 8 days after spraying the solutions.

RESULTS

The efficacy trials indicated that propylene glycol, propylene glycol + antibiotics, and 8-hydroxyquinoline sulfate were poor disinfectants, whereas Physan, isopropyl alcohol and monochloramine were excellent (Tables 1, 2, 3, 4). These tests verified our previous tests indicating that isopropyl alcohol is effective. With the field condition test, where there was continual contamination of the solutions, the 340 mgl^{-1} monochloramine solution became progressively more contaminated with time and failed to control the increasing numbers of organisms (Table 3). In contrast, the 680 mgl^{-1} monochloramine provided excellent control of the microorganisms, even under progressively greater contamination with time. The artificial inoculation test demonstrated that efficacy of monochloramine increases with increasing concentration and time. After 30 minutes, the 680 mgl^{-1} solution samples failed to produce any colonies of bacteria (Table 4). These tests indicated the slower, but more persistent nature of monochloramine in providing disinfection under conditions of high contamination.

Table 1. Efficacy of disinfectants for shear dipping under field conditions

		Bacterial colonies/dish (48 hrs. @ 27°C)			
Disinfectant	Minutes.[z]	105	225	340	580
Physan, 400 mgl^{-1}[x]		3	>6[y]	>9	9
Physan, 600 mgl^{-1}		1	2	2	2
Isopropyl alcohol, 70%		2	4	1	2
Propylene glycol, 2000 mgl^{-1}		>100	>7	>50	>50
Isopropyl alcohol, 70% + propylene glycol, 2000 mgl^{-1}		6	0	2	1
Streptomycin, 200 mgl^{-1} + Terramycin, 100 mgl^{-1} + Propylene glycol, 2000 mgl^{-1}		>50	17	22	>35

[z] Minutes after dipping began Solutions were used entire day without changing.

[y] Numbers preceded by ">" refer to coalescing colonies, making it difficult to count individual colonies

[x] mgl^{-1} = ppm

Phytotoxicity tests conducted with monochloramine on tomato plants indicated no phytotoxicity to the tops or roots to 250 mgl^{-1} monochloramine, whereas there was some phytotoxicity to isopropyl alcohol (Table 5). At 680 mgl^{-1}, monochloramine did not affect *Agapanthus* or *Asparagus*, but did affect *Brunfelsia*, *Cortaderia*, and *Lonicera* to a slight extent (Table 6). However, these tests applied considerably more solution to more roots than the very slight amount that would wipe-off a cutting blade of a shear.

Table 2. Efficacy of disinfectants for shear dipping under field conditions

		Bacterial colonies/dish (96 hrs @ 27°C)			
Disinfectant	Hours [z]	2.0	3.75	5.75	7.75
Physan, 600 mgl^{-1} [x]		>30[y]	5	10	14
Physan, 900 mgl^{-1}		1	6	3	7
Physan, 1200 mgl^{-1}		2	9	1	10
Isopropyl alcohol, 70%		1	2	2	4
Physan, 600 mgl^{-1} + isopropyl alcohol, 50%		1	>30	>30	1
Physan, 600 mgl^{-1} + isopropyl alcohol, 70%		2	1	3	3
8-hydroxyquinoline sulfate, 1000 mgl^{-1}		>60	>60	>30	>60
8-hydroxyquinoline sulfate, 2000 mgl^{-1}		>60	>60	>50	>60
8-hydroxyquinoline sulfate, 1000 mgl^{-1} + isopropyl alcohol, 50%		2	1	0	1
Monochloramine, 250 mgl^{-1}		1	1	2	4

[z] Hours after dipping begun
[y] Numbers preceded by ">" refer to coalescing colonies, making it difficult to count individual colonies.
[x] mgl^{-1} = ppm

Table 3. Efficacy of monochloramine under field conditions

		Bacterial colonies/dish (24 hrs at 30°C)				
Monochloramine	Time [z]	1100	1200	1300	1400	1500
340 mgl^{-1} [x]		2.3[y]	18.7	15.0	31.3	>49
680 mgl^{-1}		1.3	0.0	0.0	0.3	1.3

[z] Time of sampling. Start time: 800 hours.
[y] Means of 3 replicates
[x] mgl^{-1} = ppm

Table 4. Efficacy of monochloramine in artifically inoculated solutions.

		Bacterial colonies/dish (24 hrs. at 30°C)					
Monochloramine	Minutes [z]	5	30	60	120	180	240
0.0		167[y]	185	217	202	200	200
85 mgl^{-1} [x]		22	7	3	2	1	0.5
170 mgl^{-1}		19	2	35	0.3	0	0.5
340 mgl^{-1}		19	2	1	0	1	0
680 mgl^{-1}		22	0.3	0	0	0	

[z] Minutes after inoculation, sampling period
[y] Means of 3 replicates
[x] mgl^{-1} = ppm

The corrosion test indicated, unexpectedly, that 70% isopropyl alcohol was the most corrosive of the disinfectants and sodium hypochlorite, the least. Physan was more corrosive than the monochloramine, although neither produced any rust pitting as was evident with the alcohol (Table 7).

Table 5. Phytotoxicity of disinfectants on tomato plants [z]

Disinfectant	Phytotoxicity	
	Roots	Tops
Monochloramine, 250mgl^{-1} [y]	None	None
Isopropyl alcohol, 70%	Fair	None
8-hydroxyquinoline sulfate, 1000 mgl^{-1}	Slight	None
Check	None	None

[z] Pearson's Improved tomato
[y] mgl^{-1} = ppm

Table 6. Phytotoxicity of monochloramine on five ornamentals

Monochloramine	Root phytotoxicity rating [z]				
	Brunfelsia pauciflora 'Floribunda'	*Cortaderia selloana*	*Agapanthus africanus*	*Asparagus densiflorus* 'Sprengeri'	*Lonicera japonica* 'Halliana'
0.0	0.0	0.0	0.0	0.0	0.0
340 mgl^{-1} [y]	1.5	1.0	0.0	0.0	1.5
680 mgl^{-1}	1.5	1.0	0.0	0.0	1.5

[z] Rating method. 0 = no roots affected, 10 = 100% of roots affected
[y] mgl^{-1} = ppm

Table 7. Corrosiveness of disinfectants to steel, 192 hours exposure

Disinfectant	Rating [z]	
Monochloramine, 250 mgl^{-1} [y]	3	
Isopropyl alcohol, 70%	6	(rust pitting)
8-hydroxyquinoline sulfate, 1000 mgl^{-1} + isopropyl alcohol, 50%	2	(surface fixation)
Sodium hypochlorite, 250 mgl^{-1}	1	
Physan, 600 mgl^{-1}	5	
Check, tap water	4	

[z] Rating by rank, 1 = least affected, 6 = most affected. Ratings 2, 3, 4, 5 showed no pitting or rusting
[y] mgl^{-1} = ppm

Table 8. Cost of disinfectants, 1984

Disinfectant	U.S. $ per 3.785 liters (1 gal.)
Physan, 600 mgl^{-1} [z] + Isopropyl alcohol, 70%	1.85
Isopropyl alcohol, 70%	1.81
8-hydroxyquinoline sulfate, 1000 mgl^{-1} + Isopropyl alcohol, 50%	1.56
Isopropyl alcohol, 50%	1.29
Streptomycin, 200 mgl^{-1} + Terramycin, 100 mgl^{-1} + Propylene glycol, 2000 mgl^{-1}	0.15
Physan, 600 mgl^{-1}	0.04
Monochloramine, 680 mgl^{-1}	0.01

[z] mgl^{-1} = ppm

CONCLUSIONS

Monochloramine at 680 mgl^{-1} appears to be a suitable replacement for 70% isopropyl alcohol. It provides equal or better disinfection, and is considerably less expensive (Table 8). A 680 mgl^{-1} monochloramine solution costs about $0.01/gal.(3.785 liters) compared with $1.81/gal.(3.785 liters) for 70% alcohol. Because the cost of monochloramine is so low, a nurseryman can frequently discard and replenish solutions without economic concern. These solutions can easily be made from locally available materials such as liquid pool chlorine (sodium hypochlorite) or Clorox and ammonium sulphate. Pool chlorine solutions deteriorate rapidly, and a supposedly 10% labelled chlorine solution may be close to 7%, as we found with 3-month old material. Consequently, it is wise to test the available chlorine with a test kit, or assume deterioration with time and adjust the make-up of the solutions accordingly. Monochloramine solutions should be made using a ratio of 2:1 Cl:N or less to assure sufficient ammonia to form monochloramine. Concentration of chlorine using liquid sodium hypochlorite should be based on percent available chlorine rather than percent sodium hypochlorite.

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COMPUTERIZED IRRIGATION AND ENVIRONMENTAL CONTROL SYSTEMS FOR GREENHOUSE PROPAGATION AND NURSERY PRODUCTION

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As our understanding has grown of the relationship between plant growth and environmental conditions, it has become a standard practice in nursery production and greenhouse propagation to exercise control over these environmental conditions.

The advent of computerized control systems has made possible the means whereby environmental conditions are monitored, and automatically modified per the operator's preprogrammed instructions. The complexity of this function is best and most effectively performed by the computer — leav-