Current Research into Water Disinfestation for the Nursery and Cut Flower Industries

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Water disinfestation in Australian Nurseries has mainly been done using chlorination either from sodium hypochlorite or direct injection of gaseous chlorine. Some nurseries in Queensland and northern Australia have bromination and chloro-bromination systems, and ultra violet light is used in several nurseries in Victoria. An important feature shown in a survey of water quality by Beardsell and James (1995) was that it is vital that nurseries and flower farms do a complete analysis of water quality over a 12-month period before choosing a water disinfestation strategy. A recent symposium on nursery substrate disinfestation held in Belgium (Vanacher, 1995) did not provide clear information on best practices; as few quantitative and economic analyses were presented. The following paper presents a summary of the best available information on water disinfestation for the nursery industry. Much of this information has been generated by projects currently being conducted in Australia.

CHLORINE (AS HYPOCHLOROUS ACID)

Limited field and anecdotal data suggests that a 1-min exposure of 2 mg litre^{-1} of free chlorine will control *Phytophthora cinnamomi* (Smith et al., 1985). However, extensive quantitative data on other fungal plant pathogens is lacking. It has been reported that above pH 7, the amount of available hypochlorous acid in solution falls rapidly from 100% at pH 5, to 80% at pH 7, 28% at pH 8 and 4% at pH 9 (Ellis, 1991). A recent survey of nursery waste water (Beardsell and James, 1995) showed that pH above 7 was typical for Australian nurseries (average 8 in Queensland), thus acidification is likely to be required in many nurseries. Other disadvantages of chlorination are that its efficiency as a disinfectant is reduced by organic matter, iron and nitrogenous compounds (De Hayr et al., 1994). Chlorination also produces toxic by-products including trihalomethanes and chloramines. Also the dangers of chlorine gas will cause transport of this chemical to be regulated in the near the future. Chlorination cannot be recommended as best practice for water disinfestation in Australian nurseries until further detailed work testing hypochlorous acid for control of a range of plant pathogens is completed.

CHLORINE DIOXIDE

Chlorine dioxide has been shown to be highly effective for disinfestation of a range of plant pathogens including *Fusarium oxysporum*, *Alternaria zinniae*, *Colletotrichum capsici*, and *P. cinnamomi* over a range of water pH (Mebalds et al., 1995). Work is currently in progress testing its ability to control *Pythium ultimum*. Chlorine dioxide needs to be applied at an available concentration of 3 mg litre^{-1} for 8 min to control water-borne fungal pathogens (Mebalds et al., 1995). Chlorine dioxide, like hypochlorous acid, oxidises iron (Langlais et al., 1991). Poor quality water, typical of that obtained after recycling, requires higher concentrations of chlorine dioxide to overcome contaminants in the water. Sensors which regulate the amount of chlorine dioxide applied by automated equipment must be placed in such a position in the irrigation system to account for chlorine dioxide drawdown by impurities in the water.

Since Mebalds et al. (1995) also showed that the disinfestation properties of chlorine dioxide were unaffected by pH as high as 10, this method would have wide application to the nursery and flower industries in Australia which consistently have high water pH. Although chlorine dioxide equipment is more expensive than other chlorination systems, this method of disinfestation is likely to be more effective considering water quality in Australia. The only factor preventing a recommendation for chlorine dioxide as best practice for water disinfestation is that data is lacking on its phytotoxicity and on its relative efficacy on a wider range of organisms. Chlorine dioxide may be hazardous to plant and animal health, although this also has not been fully tested. A nursery in Victoria has successfully used chlorine dioxide without obvious phytotoxicity problems on a wide range of Proteaceae.

BROMINATION AND CHLORO-BROMINATION

Quantitative work on phytotoxicity and disinfestation by hypobromous acid and other bromine compounds has yet to be done on plant pathogens. This means that these cannot be considered as a best practice, although field observations indicate that chloro-bromination is effective in controlling water-borne diseases (Bodman, pers. com.). De Hayr et al. (1994) have concluded that bromine is likely to be an effective disinfestation agent, especially if nursery water has a high pH and high organic matter content.

OZONATION

The only published data on ozone control of a plant pathogen has been reported in a study on *F. oxysporum* by Yamamota et al. (1990). This work was only preliminary, and no recommendation can be made regarding control of *F. oxysporum* by ozone. Two groups in Australia, Mebalds and colleagues at the Institute for Horticultural Development and Alexander and van Lewin at the University of New England, are currently investigating the value of ozone for controlling plant fungal pathogens. At this stage ozone can not be recommended as best practice for water disinfestation, although it appears promising because of its lack of potential residual phytotoxicity. Hoigné (1994) has shown that ozone demand in water increases with ammonium, nitrite, ferrous, carbonate, and bicarbonate levels. High pH also reduces the half life of ozone. The high alkalinity (bicarbonate levels) of nursery water in South Australia may limit the application of ozone in that State.

ULTRA VIOLET RADIATION

Ultraviolet (UV) radiation is an effective and environmentally friendly method of controlling *P. cinnamomi*, *F. oxysporum*, *C. capsici* and *A. zinniae* if water has high UV transmission (greater than 50% UV transmission after filtration) and exposure dose is at least 5.0×10^5 $\mu W\ s^{-1}\ cm^{-2}$ (Mebalds et al., 1995). *Alternaria zinniae* has dark-coloured spores and is the most difficult to kill with UV radiation. This organism should be used as a standard for testing the efficacy of UV equipment. Equipment for irradiating water with UV must be designed so that pressure changes in pipes between the pump and the UV reactor are minimised, otherwise protection of pathogens from the radiation may occur. Water must also be filtered and turbulent flow is needed in the UV reactor otherwise organisms may be protected from radiation exposure. Ultraviolet radiation can be recommended as best practice for nurseries which have recycled water with UV transmission greater than 50% at a wavelength of 254 nm because of its environmentally friendly operation and low cost. However few nurseries will have recycled water of such high quality. Dissolved solids are the major cause of poor UV transmission; the colour of the water strongly influences UV transmission (Beardsell and James, 1995).

HEAT

Although heat is used widely in Europe to kill plant pathogens in water it is likely to be very expensive in Australia. If waste heat can be used, it might be considered, however Runia (1995) has shown that water must be heated to 95C for at least 30 sec for adequate disinfestation.

FILTRATION

Microfiltration has been shown by Runia (1995) to be impractical due to clogging of filters by poor quality water in European nurseries. It is also very costly. Biologically active sand filtration has been shown to reduce pathogens in waste water; sand filters may not however control *F. oxysporum* (Wohanka, 1995) and some viruses (Berkelman et al., 1995). Filtration is an important pre-treatment to improve the efficacy of other disinfestation methods, and sand filtration may be useful in conjunction with these.

CONCLUSION

Water quality is the most important factor in choosing a water disinfestation method. Clean water with a high UV transmission can be successfully disinfested using UV radiation. Chlorine dioxide at a residual concentration of 2.6 mg litre^{-1} can be used to disinfest poor quality water, and has scope for greater use in the nursery industry. There is insufficient data available on ozone and bromine compounds for disinfestation of plant pathogens to make recommendations for their use in water of variable quality.

Acknowledgments. We would like to thank Keith Bodman, Dick Wall, David Matthews, David Nichols, John Churchus, Chris Rolfe, Ian Atkinson, Frank Greenhalgh, John Osmelak and Martin Barlass for their support and the provision of information. Also we would like to thank the State Chemistry Laboratory of Victoria for chemical analyses and Graham Hepworth for statistical advice. This research was funded by the Horticultural Research and Development Corporation, the Nursery Industry Association of Australia, the Victorian Federation of Flower Growers Group, and Agriculture Victoria.

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