Integrated Pest Management

I've decided to add this new section to emphasize the need to establish an Integrated Pest Management (IPM) program at your nursery, and to highlight some of the innovative new approaches that are being developed.

Also See: "Limiting Factors: pests" in Cultural Perspectives Section, and "Common-sense pest control" in Special Publications Section.

Stop Using Traditional Pesticides and See What Happens

During the discussion at a recent meeting, someone suggested this interesting concept which is the inverse of the recommended practice of always leaving "control" plots whenever you apply a pesticide. Instead of applying those routine pesticide applications to the entire crop, leave a small control section untreated and see if a pest problem develops. Nurseries that have tried this approach have found that they can actually have am increase in seedling yield while saving money by using less pesticide: ***(Figure 5)***.

Source:

Dumroese, R.K.; Wenny, D.L.; Quick, K.E. 1990. Reducing pesticide use without reducing yield. Tree Planters' Notes 41(4): 28-32.

Using Chlorine to Prevent Nursery Diseases

One of the basic tenets of Integrated Pest Management (IPM) is to minimize the use of pesticides. We all realize that some pesticides are necessary to raise a crop of quality tree seedlings, but agree that we should also use the least toxic pesticides. When chlorine is used as a pesticide, it can help prevent pests from entering the nursery environment-another keystone of IPM. By eliminating the source of nursery pests, the need for more toxic pesticides is significantly reduced.

In the form of laundry bleach, chlorine is one of the most available and affordable chemicals in the world. When most people they think of bleach, they don't think of it as a pesticide. For years, however, nursery workers have used bleach solutions to sterilize greenhouse benches, floors, and other surfaces in the propagation area. Chlorine is also commonly used to treat irrigation water that is infected with fungi or other pests. When used properly, chlorine is a safe, easy-to-use chemical that should be a basic tool in nursery culture.

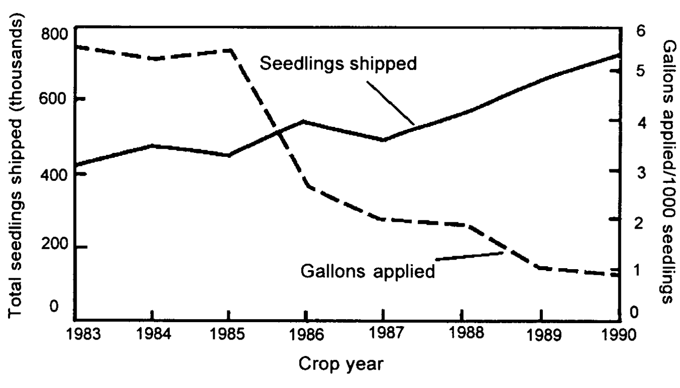

Figure 5. Nurseries have found that often they can maintain or even increase seedling yield while reducing use of traditional pesticides.

Basic Chemistry and Mode of Action.

Chlorine is a very irritating, heavy, greenish-yellow gas with a very pungent odor; therefore, for operational purposes, chlorine is always applied in a solution. Chlorine solutions are strong oxidizing agents that kill organisms by chemically "burning" their tissue. Chlorine has two modes of action: as a sterilant, which destroys all organisms, and as a disinfectant, which selectively destroy pests.

When any form of chlorine is added to water, hypochlorite (HOCl) and chlorite (OCl^-) are formed. The HOCl form is the most effective disinfectant. The standard measure of chlorination effectiveness is defined as the sum of HOCL and OCL- molecules, which is known as free residual chlorine. Other synonymous terms are available chlorine, total chlorine, and free chlorine. Any of these chlorine terms should not be confused with the chloride ion (Cl^-) which is important for water quality but has no disinfectant properties.

Many other chemicals react with the chlorine in solution and reduce its effectiveness. The chemistry of chlorination is pretty scary but suffice it to say that enough chlorine must be added to result in an effective level of available chlorine *(**See Figure 6**)*.

Sources of chlorine.

Chlorine is commercially available in three forms:

Chlorine gas (Cl_2)

Chlorine gas is furnished commercially as a liquid in pressurized metal cylinders; when the gas is bubbled through water, it forms HOCl and OCl^-. Although this is the simplest source from a chemical standpoint, Cl_2 is very toxic and its corrosive nature makes it difficult to handle operationally.

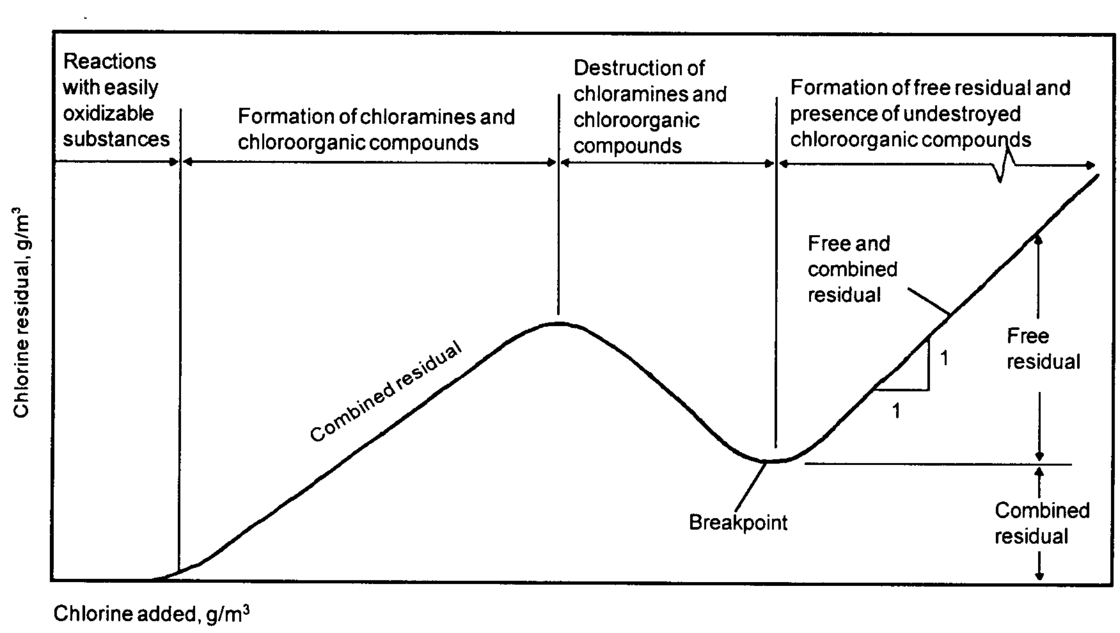

Figure 6.

Many things combine with chlorine to reduce its activity in solution, and so enough must be added to produce an effective concentration of "free residual" chlorine.

Calcium Hypochlorite [$Ca(OCl)_2$]

Calcium hypochlorite is a common form of chlorine used for domestic water treatment, and is available commercially either as a granulated powder, large tablets, or liquid solutions. Most commercial formulations are 65% calcium hypochlorite, with the balance being stabilizers and inert materials. Calcium hypochlorite is relatively stable as long as it is kept free from water and may be stored for extended periods in solid form. However, the same property that makes calcium hypochlorite stable also makes it difficult to dissolve completely in water. This is particularly true in cold water and so calcium hypochlorite always should be dissolved in a small quantity of warm water before use. Large tablets can be added directly to the solution where it will slowly dissolve to yield a continuous supply of chlorine to the water. However, care should be exercised in the placement of the tablets to ensure proper mixing of the chemical and the water.

Sodium Hypochlorite (NaOCl)

Liquid household bleach is the most common form of chlorine used in horticultural applications. Although it is also available in solid form, sodium hypochlorite does not store well, readily absorbing moisture from the atmosphere and releasing chlorine gas. Household bleach usually is marketed as an aqueous solution containing 5.25% sodium hypochlorite. Commercial bleach solutions containing from 9.5 to 15% sodium hypochlorite are also available in large containers from chemical suppliers, but are not as stable as household bleach. Sodium hypochlorite solutions are generally more expensive than granular calcium hypochlorite due to the additional shipping and handling costs associated with the water.

Where a continuous supply of chlorinated water is required, concentrated solutions of sodium or calcium hypochlorite can be injected. Chlorine injector systems are commercially available that consist of a feed tank and an electrically operated pump with a variable output. Chlorine injectors must always be installed with an approved check valve arrangement to prevent back flow into the fresh water system.

Formulations, Units, and Monitoring

With chlorine gas, chlorination is accomplished by bubbling a metered amount of gas into water. Because of the danger involved and the expense of the metering equipment, the use of chlorine gas for chlorination usually is limited to large-scale treatments of irrigation water supplies. Injection of chlorine gas is specified and monitored in parts per million (ppm) of available chlorine.

Liquid bleach or solid calcium hypochlorite are mixed with water to form solutions. Unfortunately, chlorine solutions are formulated with different units than those with which they are monitored which can be confusing. For ease of formulation, chlorine solutions are mixed using volumes of liquids or weights of solid products whereas their effectiveness is monitored in ppm. Bleach solutions are generally calculated as either % bleach or % sodium hypochlorite; these are not the same, however, and growers must be aware of the difference. For example, a "10% bleach solution" is a standard concentration which contains 1 part bleach: 9 parts water. This is NOT the same as a "10% sodium hypochlorite" solution because liquid bleach contains only 5.25% sodium hypochlorite. Actually a "10% bleach solution" is equivalent to a "0.5% sodium hypochlorite" formulation.

For monitoring, however, we need to use ppm units. The calculations to determine the ppm of available chlorine in a solution are relatively simple. For example, to calculate the available chlorine in a 10% bleach solution:

First, calculate % available chlorine (HOCl + OCl):

Laundry Bleach = 5.25% NaOCl

Atomic Weights: Na = 23, O = 16, Cl = 36, Total = 75

$$\frac{52}{75} = 0.69$$

$$0.69 \times 5.25 = 3.6\% \ (HOCl + OCl)$$

Next, convert to ppm:

$$\frac{3.6}{100} = \frac{X}{1{,}000{,}000} \qquad X = 36{,}000 \text{ ppm}$$

Therefore, a fresh 10% bleach solution contains 36,000 ppm of available chlorine. Remember, however, that this value will decrease as chlorine volatilizes and is chemically tied-up on other dissolved and suspended materials in the water ***(See Figure 7)***.

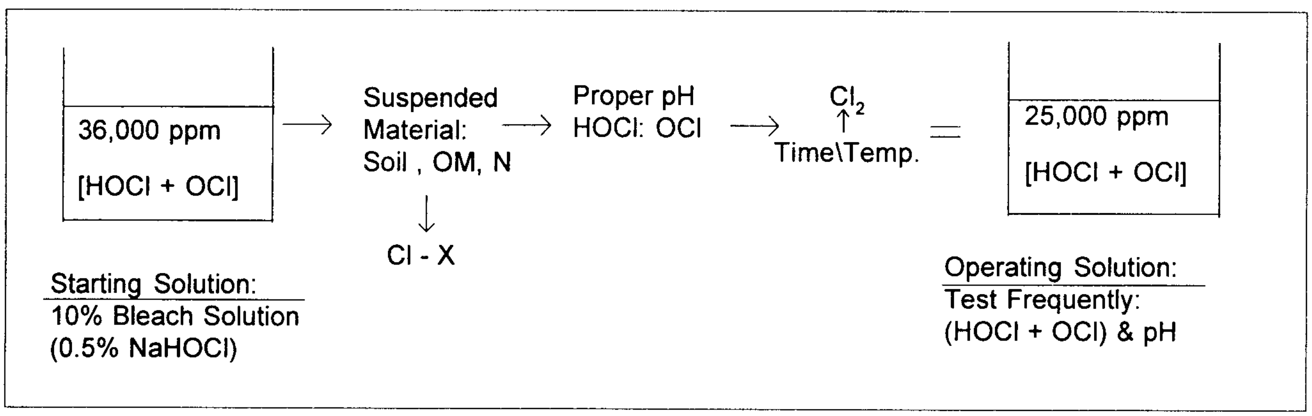

Figure 7.

Although bleach solutions are formulated as % product by weight or volume, chlorine effectiveness is monitored in parts per million (ppm) of available chlorine [HOCl + OCl]

Complete monitoring of chlorine in the work environment requires 2 different test kits: one for the chlorine gas in the air for worker safety, and one for available chlorine in solution to monitor chlorination effectiveness. Portable gas analysis kits are available for approximately $400-500, including models that can check 8-hour worker exposure limits. Water test kits using the DPD colorometric test for chlorine can be purchased for $300-400, but can only read the "available chlorine" in the 0200 ppm range. The less expensive ($40) swimming pool kits only have a range up to 10 ppm. Because of these limited ranges, these test kits will not be useful for all nursery applications.

Types of Applications

Let's look at some recommended applications for chlorine solutions that appear in the literature. When other formulations are given, I've converted to % laundry bleach solution to make comparisons easier:

Surface disinfection of propagation material: Chlorine solutions can be used to remove pathogenic fungi from the surfaces of seeds prior to sowing, or sanitize cuttings prior to sticking:

Seeds - *"Place seeds loosely in mesh bags and soak for 10 minutes in a 40% bleach solution ".* This procedure eliminates *Fusarium* spp. and other potentially pathogenic fungi from conifer seeds and is a recommendation for relatively hard seeded species such as *Pinus* spp. Either the solution concentration or the soaking time may have to be decreased for softer-coated seeds such as *Fraxinus* spp. After treatment, rinse the seeds thoroughly in running water for at least 48 hours.

Cuttings - *"Dip stems in a 0.5% sodium hypochlorite solution for 20 minutes "* (=10% bleach solution). This treatment is recommended to remove crown gall bacteria which are carried on the surface of rose cuttings. The concentration and treatment times may be much less for more sensitive plant material, and so growers must experiment with their species and operating conditions.

Sterilization of Used Containers and Surfaces in Propagation Area:

Benches and other surfaces - *"Clean thoroughly and then wipe with a bleach solution* of *1 part bleach: 9 parts water"* = (10% bleach solution).

Containers - *"Clean out all growing media, rinse, and store overnight. Dip into a soak tank* of *0. 5% bleach solution and let stand for at least 10 seconds ".* This published recommendation sounds like a very dilute concentration. Maybe they mean a 0.5 % NaOCl solution which would be the standard 10% bleach solution.

Disinfecting Irrigation water - *"Chlorine dosage should be great enough to provide a residual of 0.4 ppm with a contact time of 30 minutes ".* Chlorine injectors are usually followed by some sort of temporary storage so that the chlorine can have time to work. The presence of waterborne pathogens such as *Pythium* spp. and *Phytophthora* spp. can be detected with apple or pear baits.

Factors that affect chlorine activity

Chlorination is a dynamic chemical process, and effective chlorination is influenced by a number of factors. Proper chlorination requires frequent monitoring of the solution and a thorough understanding of the factors involved:

1. Concentration.

The quantity of chlorine compound that must be added to a quantity of water in order to maintain a given concentration depends on the available chlorine content of the compound, the concentration of the compound, the volume of water to be treated, and the amount lost due to the reaction with other chemicals in the water. Experiment with solution concentrations and treatment times, especially when sanitizing plant material. The chlorine concentration will vary considerably between different applications. For example, water treatment requires only about 1 ppm available chlorine compared to the 36,000 ppm in a 10% bleach solution.

2. Time. The effectiveness of the chlorine treatment depends greatly on the relationship between exposure time and concentration. Most of the sanitizing action of the chlorine will often occur within the first few minutes of exposure. The type of application will also affect the exposure time. To sanitize living tissue, a longer soak with a weaker solution may be more appropriate, whereas a shorter dip in a higher concentration is needed to sterilize containers. Because of the many variables that are involved, experience is the best guide to the correct combination of concentration of chlorine and treatment time.

3. pH.
Solution pH has a significant effect on the activity of chlorine in water. When chlorine gas or one of the hypochlorite salts is added to water, each will generate C12, HOCI, and OCI- in various proportions, depending on the pH of the solution ***(See Figure 8)****. To* maximize the proportion of HOCI and, hence, the effectiveness of the solution, the pH should be kept around 6.5. The pH of irrigation water supplies may vary from moderately acid to moderately alkaline, and stabilizers included in many commercial chlorine products can raise pH significantly. Chemical buffers can be used to maintain the pH in the desired range, and the pH of the chlorine solution should be monitored regularly.

4. Organic matter.
Chlorine has a particular affinity for organic matter. Dirty water "uses up" the available chlorine much faster than clean water ***(See Figure 7)****.* The amount of free available chlorine in the solution constantly decreases as chlorination takes place. Therefore, the chlorine level should be checked and renewed regularly when dirty water is used - for example, when used containers are being sterilized. For the same reason, containers should be cleaned thoroughly before putting them in the chlorination tank.

5. Temperature.
The activity of chlorine increases as the temperature of the solution increases. In situations where the water temperature is low, there is a significant reduction in chlorine activity. On the

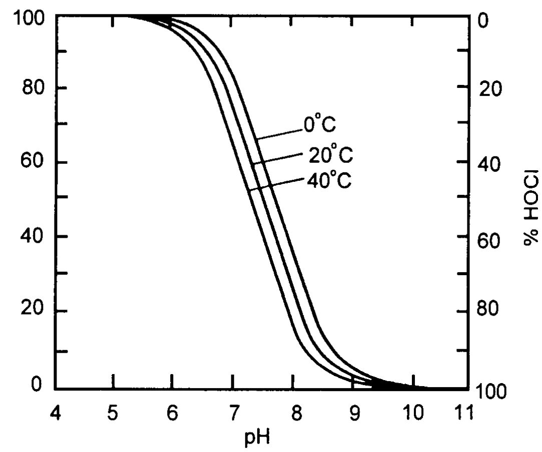

Figure 8.

Distribution of [HOCl] and [OCl-] as a function of pH and temperature.

other hand, solutions that are too warm will cause excessive Cl_2 volatilization ***(See Figure 7)****.*

6. Growth stage of the pathogen . Pathogens can be present as either mycelia or spores. Chlorine will readily kill mycelia, but some fungal spores are 10 to 1000 times more difficult to kill. Chlorine kills only on contact, not systemically, and is only effective on exposed pathogens such as those suspended in water or those on the surface. But chlorine cannot kill pathogens it cannot reach, such as those imbedded in root fragments imbedded in the walls of a Styrofoam container. Soaking materials before treating stimulates spore germination and activates mycelia, making pathogens easier to kill.

Worker Safety
Dilute chlorine solutions can irritate skin and bleach clothing, so workers should always wear protective gloves and aprons. The airborne exposure concentration for chlorine determines the limit for worker exposure. Chlorine vaporizes readily, and the odor of chlorine is detectable between 0.2 and 0.4 ppm. Above 0.5 ppm,

chlorine vapors irritate the eyes, nose, and throat of exposed workers although this varies considerably between individuals. The current legal exposure limits are 1 ppm for an 8-hour workday and 0.5 ppm for short-term (15 min.) exposures. Be sure and check your Material Safety Data Sheet for more specific exposure, storage, and handling information.

Wastewater considerations

Large volumes of spent chlorinated water may be considered an industrial waste water if it is discharged to a municipal wastewater treatment plant or to surface waters. Operators of large scale chlorination operations may be required to obtain a discharge permit. On a more practical basis, just letting a tank of bleach solution set for a few days until the smell of chlorine is gone should take care of the problem. If you want to be absolutely sure, however, check with your local water quality officials.

Practical rules for successful chlorination: A summary

1. Clean materials before treating and change the water frequently. Chlorination efficiency is very poor with dirty water and therefore seeds, cuttings, containers, and propagation surfaces must be cleaned before treatment. Chlorine solutions should be changed regularly.

2. Monitor the chlorine solution. Chlorine concentration and pH should be monitored frequently with test kits, both to maintain effectiveness and prevent health problems.

3. Ventilate the work area. Levels of chlorine great enough to cause worker discomfort are excessive and well above that required for proper sanitation. In the absence of air-monitoring equipment, chlorine concentrations are usually adequate if they can be smelled by a person not desensitized by long exposure to the odor. The concentration is too high if workers are irritated continually by the odor.

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