This article was listed in Forest Nursery Notes, Winter 2008

108. Growing insect-free plants with new technology. Gill, S., Schuster, C., Rosenkranz, G., and Shrewsbury, P. International Plant Propagators' Society, combined proceedings 2006, 56:330-339. 2007.

Growing Insect-Free Plants with New Technology©

Stanton Gill
Regional Specialist, Central Maryland Research and Ed Center, University of Maryland Cooperative Extension and Professor, Montgomery College Landscape Technology Program, Germantown, Maryland U.S.A.
Email: Sgill@umd.edu

Chuck Schuster
Maryland Cooperative Extension - Montgomery County, 18410 Muncaster Road, Derwood, Maryland 20855 U.S.A.

Ginny Rosenkranz
Maryland Cooperative Extension - Wicomico County, PO Box 1836, Salisbury, Maryland 21802-1836 U.S.A.

Paula Shrewsbury
Department of Entomology, University of Maryland, 4112A Plant Science Building, College Park, Maryland 20742 U.S.A.

Suzanne Klick
Technician, Maryland Cooperative Extension, Central MD Research & Education Center, 11975 Homewood RD, Ellicott City, Maryland 21042 U.S.A.

DEALING A BLOW TO PESTS AT THE PROPAGATION STAGE

Can very warm water kills pests and make a nursery plant propagator happy and rich? Yes to the warm water killing pests and yes to the part about making nursery professionals happy. Whether you can get rich using this method is up to you. We think that multiple potential benefits can be found using a hot water immersion system to decimate insects, or should we say cook insects, at the propagation stage. This method was developed through University-based research in Hawaii and at the University of Maryland.

Many nursery plant propagators are anxious to adopt effective, cost-efficient methods of nonchemically controlling pests. Concerns over worker's unnecessary exposure to chemicals has prompted many owners to look for alternative methods to deal with insect and mite control that places less reliance on pesticides. Greater regulation on the use of chemical pesticides has created an opportunity to look to other methods of dealing with pests. The idea of using hot water treatments to control pests on nursery cuttings is relatively simple but effective. Most pests of ornamental plants can survive at high temperatures, but there is a temperature window at which insect pests die but which plant material tolerates.

Funding from Maryland Nursery and Landscape Association (MNLA) and the Northeast IPM Group (NEIPM) enabled us to build a portable hot water immersion system that is economical and relatively easy to construct and operate by plant propagators. The system involves an instant hot water heater that rapidly heats water to the proper temperature and recirculates the water around plant cuttings. Propagation plant material is placed in treatment mesh baskets and placed in a recirculating hot-water system. Growers are likely to adopt methods that are practical and easy to use — criteria that this system meets.

We tested multiple temperatures and treatment times for 13 species of woody plant and herbaceous plant material and a couple of greenhouse species. We established threshold temperatures at which cuttings of these species can be treated without suffering injury. We also evaluated the impact of hot water treatment on four different insect and mite populations on plant cuttings taken.

INTRODUCTION

Nursery managers will propagate many species of nursery plant material by taking cuttings from stock plants and rooting them in mist chambers before moving them to production growing areas. A stock plant can have a small infestation of insects or mites that are difficult to detect such as scale, mealybug, thrips, aphids, or spider and broad mites. Growers strive to propagate from clean plant material, but sometimes the pests are so small or the pest is found in cryptic parts on the plant that they go undetected.

In a mist chamber it is nearly impossible to apply insecticides since the foliage is being constantly syringed off by the frequent mist cycle needed to keep plants moist during the rooting stages. A systemic insecticide applied to the substrate is not practical since the plants do not have roots to pull up the soil-drench-applied insecticides. Some nursery managers have resorted to dipping cuttings in dip tanks with pesticides in the hope of killing pest before they are moved into mist greenhouses for rooting. The problems with this approach are multi-fold: (1) Most pesticides are not labeled for this usage, and therefore, there are no labeled rates and directions. (2) Exposure risk to pesticides by employees dipping the plants is very high. (3) There is not a good way for owners to dispose of the remaining pesticide dip when the process is completed.

The idea of using hot water treatments to control pests is relatively simple but effective. Most pests of ornamental plants can survive at high temperatures, but there is a small temperature window at which insect pests die but which plant material tolerates. Dr. Hara at Hawaii University has tested the hot water bath method on a number of plant species and found that 49 °C (120.3 °F) for 1–10 min gave effective control of several species insects including aphids, scale, mealybug, and mites on nursery plant cuttings. Hara tested hot water treatments on tropical plant material.

In our trials we established the threshold temperatures that temperate zone plant material can be safely treated with hot water and not damage the plant material. We need to also establish whether these hot water treatment temperatures and length of treatments that are safe on plants also kill the pests.

For this project we worked with several Maryland nurseries in evaluating temperature ranges and length of treatments that are safe. We let the nursery managers select plant material that had damage from known pests that are commonly found on stock plants. Special thanks to the following nurseries for working closely with us in this project: Chesapeake Nursery, Woodland Nursery, Marshy Point Nursery, Ivy Farm and Hillcrest Nursery, the Perennial Farm, Bluemel Nursery, and Greenstreet Growers Greenhouses.

HOT WATER AS A SOIL DRENCH TO CONTROL SOIL PESTS

In Ohio, Bob McMahon of Ohio State University has been working on controlling greenhouse pests using hot water drenches. In his studies he found that treating soils using hot water drenches and taking the soil up to 110 °F kills larvae of fungus gnat very effectively. He also tested the tolerance of poinsettia and New Guinea impatiens to hot water drenches. McMahon found that poinsettia could tolerate soil temperatures up to 135 °F without damage. New Guinea impatiens tolerated even higher temperatures up to 150 °F without damage. McMahon has applied 24 ounces of water to 6-inch pots, waited 3 min and applied a cooling drench of water at 20 ounces per pot.

Our approach at the University of Maryland Cooperative Extension has been a little different. We are looking at treating plant cuttings taken from infested stock plants and cleaning them up so they are relatively pest free. In our system whole plant cuttings are submersed in water held at a constant temperature for a set amount of time with the water being recirculated around the plant cuttings. The treated cuttings are then cooled using water at 50–60º F, for 60–120 sec. The cuttings are then stuck as in normal propagating methods.

OBJECTIVE: DEVELOP AN EFFECTIVE IPM TOOL FOR NURSERY MANAGERS

Our lofty goal was to build a device that is affordable (under $4,000), portable, and practical for treating large numbers of cuttings. The system we chose was based on a modified model developed by Dr. Arnold Hara of Hawaii University. The system uses an instant hot-water heater and propane gas for the energy source. Hot water is circulated through a 100-gal stock tank and plant material is lowered into the water in PVC netted cages. Temperatures are monitored as the water moves to the tank and a thermostat records the temperature of the recirculating water to make sure the temperature is constant and even.

Circulation and temperature uniformity in the treatment tank is achieved though a circulation grid consisting of a centrifugal pump and plumbing system. The pump outlet is split to both sides of the tank, causing the water to follow the oval-shaped perimeter of the tank. Our Extension agricultural engineers designed the piping, placement of thermocouplers, and control values. We used temperature gauges to measure the temperature in various parts of the stock tank to determine if the temperature was uniform. The first pump placed on the system did not give adequate circulation, and we had variation in the temperature in the stock tank. We requested that our agricultural engineer increase the horsepower to move the water around the plant cuttings. This large pump greatly helped in making the temperatures in the treatment tank much more uniform. A circulation control value was placed on the system so we could increase or lower the recirculation rate as desired. It would be increased when the tank was completely filled with treatment cages and we needed maximum flow around the cuttings.

Design of the System. The hot water immersion system has two main systems. The first is the water heating system with the instantaneous water heater and its water and gas supplies that provide the hot water for the immersion tank. Thermometers, control valves, and pressure gauges are part of the system to monitor and to help achieve the hot water necessary. The second system centers on a pump that circulates the water in the immersion tank through pipes and risers with nozzles to mix the water and push it into the plant material. Using control valves the discharge from the pump can be directed into the tank to mix the water or the water can be directed away from the tank to dispose of it. Cooled water might be recycled to the heater.

Certain considerations for the design are important in order to make a good functioning system. The water heater has a given capacity for heating water, and that defines the water flow rate and water pressure required for the system. It sets the limitation on the amount of hot water that will be available to initially fill the immersion tank and the amount of hot water available to maintain a given temperature. Since the water temperature is critical to the success of the immersion process, insulation was placed around the immersion tank to reduce heat loss, thus temperature change is reduced. The ability to monitor the water temperature going into the immersion tank and the temperature of the water being circulated is essential. A good water circulation system to stir the water is desired to maintain temperature uniformity.

Water Heating System. An instantaneous water heater was selected for the portable hot-water immersion system. For a stationary system a regular commercial or residential-type water heater with a fairly fast recovery rate should work. For the purpose of clarity, the brand name, and model numbers of the actual equipment used to build the system will be given; this does not mean that other equipment could not be used nor is it an endorsement for any specific equipment.

For the University of Maryland unit, a Paloma Automatic Gas Water Heater Model PH-24M-DP for propane gas was used. The unit has a rated input of 178,500 Btu/h on high and a 37,700 Btu/h rate at half way on. This translates into a 90 °F rise in water temperature at a water flow rate of 3.17 gpm on high burner rate and a 100 °F rise in water temperature at a water flow rate of 2.85 gpm on high burner rate. This is important design information because this is the maximum water heating rate for the system. Other data to note is that a water pressure of 12.9 psi is required to push the water through at the high rate of heating. This pressure differential is required for the flow control valve of the heater to work properly. The section on operating the system will illustrate this.

The instantaneous heater turns on as the hot water tap is opened and cold water flows through the heat exchanger. A pressure differential switch controls flow. A water temperature knob can be adjusted to set the water temperature at a given flow rate. For this application the “HOT” setting is used.

System Operation.

- Determine the high temperature intended for the process. We found that most plants can tolerate 120–125° F for varying amounts of time. Some more sensitive plant material will need lower temperatures. It is much more efficient to start at the high temperature and work down to a lower temperature than to try to increase the temperature after starting at a low temperature.
- Allow the water to flow into the tank to a point that will cover the baskets used to hold plant material and be above the blue suction line for the circulation pump. Temperature stabilization is important. The lid will help hold water temperature and should be used whenever possible.

- Allow at least 15 min for tank temperature to stabilize before starting the process of putting plants in the tank. Tank temperature can be monitored using the circulation pump system and temperature gauge located to the right of the pump motor. Pump motor control is located below pump motor.

Establishing Killing Temperatures for Insects and Mites. Hara, in his research work on hot water immersion, placed plant cuttings into a netted cage. He preconditioned the plant material by holding the cuttings at 40 °C (104ºF) for up to 15 min. The plant cuttings and net holding chamber is removed and the temperature is then raised to 49 ˚C (120 ºF) for 8-12 min. After the disinfecting treatments at 49 ˚C the plants are then cooled to ambient air temperatures, which was approx. 24 ˚C (74 ºF) for 5-6 min. The cuttings are then stuck into a mist chamber.

Table 1. Hara noted that hot water treatment at 49 °C (120 °F) kills the following pests:

Insect (treated with hot water)	Temperature (°C)	Time to obtained > 99% mortality (min)
Ants	49	0.5
Aphids (banana and cotton)	49	1.0
Taro root aphid (on roots)	49	5.5
Cockerell scale	49	8.0
Green scale	49	10.0
Mealybug (obscure and citrus)	49	12.0
Spiraling whitefly	49	12.0
Root mealybugs (potted)	46	Variable due to density of root ball

Testing out the System performance. We set up tests to evaluate the hot water recirculation system when under a working load of cuttings. We quickly found out that if we brought the temperatures up to the desired temperature and then inserted cages holding the cuttings, the water temperature dropped. We experimented with heating up the water in the stock tank to higher temperatures then slowly lowering the temperatures. Through repeated trials we found that it is best to run the temperatures up to 145–150 ˚F for at least 30 min to heat up the stock tank and the surrounding insulation. In the colder weather of the winter it may require up to 45–60 min to adequately heat up the tank. We also raised the temperature 1 ˚F warmer than the target temperature to compensate for the lowering of the temperature when the cutting baskets were lowered into the treatment tank.

Another modification was the addition of an insulated lid with a 1-inch polystyrene layer that covered the treatment stock tank. The insulated lid combined with pre-heating the tank to 145–150 ˚F for 30 min worked well. Slowly introducing water from a hose to bring the temperature down to the desired temperature worked well. The preconditioning of the stock tank allowed us to maintain a constant temperature of the water for 20–30 min.

Temperature Adjustment and Treatment Cages. To improve the ease of placing and removing the cuttings into the tank we constructed large cages of 18 inches X 18 inches. We found these cages were too large and cumbersome for treating a small number of cuttings at a time. These larger cages might work if a grower were treating large numbers of cuttings of the same plant species. For our trials smaller was better. We modified our experimental cages by making them a compact 12 inches X 12 inches. Since the cages were made of PVC plastic pipe they tend to float up in the tank. We drilled holes into the PVC pipe so the cages sank into the water in the tank. These smaller cages appeared to fit the cuttings better with fewer floating out in the main body of treatment tank.

We were able to fit up to six cages into the stock tank during a treatment. The plastic mesh used to cover the cages had a 3/4-inch opening to allow the water to flow through the cage. This 3/4-inch opening worked well for most of the woody cuttings with very few cuttings escaping. When testing the herbs we had to place the cuttings into finer silk mesh bags and place them in the cages to keep them from escaping from the cage into the stock tank.

Plant Material Tested in 2004–2006. Each treatment temperature and time interval had 5 replications. Immediately after being taken out of the hot water treatments the cuttings were moved into water at 65–70 °F for a cool down period of 5 min. Cuttings were then immediately stuck into substrate and placed under a timed interval mist system. Cuttings were observed over a 6- to 8-week period. We noted if the treatments caused scorching of foliage, dieback of the cutting, or lack of rooting. If any damage was recorded at temperature or time interval it was determined to be unacceptable.

In Table 2 we report the lowest temperature and time interval that did not cause burning, dieback or lack of rooting of the cuttings. Hara noted in his work in Hawaii that 49 °C (120 °F) was the temperature that gave effective kill of mealybug, armored scale, aphids, whitefly, and ants. He noted that 46 °F (117 °F) also killed pest but required longer treatment times of 30 min which often caused injury on plants he tested in Hawaii.

A temperature of 120° F appears to be the threshold above which injury is incurred on several species of plants in our trial. We found that 120° F at 10- to 20-min treatment times appears to be safe on azalea (*Rhododendron*), ivy (*Hedera* sp.), boxwood (*Buxus* sp.), Leyland cypress, and arborvitae (*Thuja*) 'Green Giant'.

Treatment of Insects and Mites.

Boxwood Mite Control. Boxwoods were obtained that had heavy population of boxwood mite (*Eurytetrancychus buxi*) eggs present and damage to 90%–100% of the foliage from last season. Cuttings were taken from the plants and twenty 6-inch branch tips, taken randomly, were examined and the number of eggs recorded to establish a precount average number of eggs. Only eggs were present at this time of year since the boxwood mite overwinters. Growers take cuttings during the winter months for rooting cuttings. We felt this was appropriate to evaluate whether the hot water treatment would kill the eggs. On 7 April 2005, 6-inch cuttings were treated at 120° F for 15 min. This temperature and length of treatment was chosen since this was determined to be the highest temperature and greatest

Table 2. Plants treated in 2004 to 2006.

Nursery supplying plant material	Plants used in trail and month tested	Highest temperature (°F) plants will tolerant	Greatest length of treatment time (min) without damage to plant material	Additional comments
Marshy Point Nursery	*Rhododendron* 'Rosebud', plants treated 13 August	120	10	120 °F for 15 min caused 50% treated plant foliage to scorch
Ivy Farm, Eastern Shore of Virginia	*Hedera helix* 'Wingertsburg'	120	15	At 20 min 75% of plants were scorched
	Hedera helix 'Marginata of Hibbard'	120	20	125 °F at 10 min or more resulted in foliage scorching
	Hedera colchica plant treated in April	120	15	At 20 min 25% of foliage was scorched. Treatment at 125 °F for 10 min caused 20% foliar injury. At 125 °F for 15 min or more caused over 50% foliar scorching.
Chesapeake Nursery	*Cotoneaster* ·×suecicus (syn. *dammeri*) 'Coral Beauty' Treated 6 June 2004	120	10	At 115 °F the plants can stand up to 20 min with no foliage damage
	Viburnum plicatum f. *tomentosa* 'Shasta' treated June 6	120	10 min with 30% of plant showing leaf scorch	Plants treated at 155 °F can tolerate 20 min with no injury
	Ilex crenata 'Convexa' treated 6 June	115	10 min with 40% of plants damaged	Not very tolerant of treatments

	Pieris japonica	120	20	Less than 20% foliar injury, all cutting survived.
Woodland Nursery	*Buxus sempervirens* 'Rotundifolia' treated in August	120	15	At 125 °F for 10 min 70% of plants dead
Hillcrest Nursery	*Salvia officinalis* (sage)	112	20	At 115 °F for 15 min 10% of plants dead, at 20 min 50% dead
	Artemisia dracunculus (tarragon)	110	0	At 110 °F all plants, tarragon appears very heat sensitive
	Rosmarinus officinalis (rosemary)	115	10	At 115 °F for 20 min plant ok
Bluemel Nursery of Harford County and Perennial Farm of Baltimore County	*Miscanthus sinensis*			
CMREC Nursery plants	×*Cupressocyparis leylandii* (Leyland cypress)	120	15	120 °F for 20 min suffered > 40% damage. Higher temperature caused 100% death
	Thuja 'Green Giant'	120	10	Plant looks good for 2 weeks then browning and dieback occurred on anything above 120 °F or times treatment times of 15 min or longer
Greenstreet Growers of Lothian, Annapolis	New Guinea impatiens	120	20	Plant cuttings appears very tolerant of 120 °F treatment

length of time we could treat without causing damage to the cuttings in previous temperature phytotoxicity trials. The level of control of boxwood mite at 120 °F for 15 min gave 100% control on the treated plants (Table 3). Plants treated at 115° F for 15 min only had a little over 60% control.

Fern Scale Control. Liriope plants infested with fern scale, *Pinnaspis aspidistrae*, were used in the trial. Soil was removed from the root system before treatment in the hot-water immersion system. Twenty liriope plants were examined and recorded the number of 3rd-instar females present. This established an average number of scales per plant for the pre-treatment count.

Plants were then treated at 120° F for 15 min and 115° F for 15 min. Plants were then potted and placed under a mist system. Untreated control plants were also placed under mist. A treatment of 115° F was not sufficient to kill the scale but 120° F for 15 min gave 99% control (Table 3).

Miscanthus mealybug. Container-grown miscanthus plants infested with miscanthus mealybug, *Miscanthicoccus miscanthi*, were obtained from a local grower. A pre-count was taken on 20 plants to establish an average number of overwintering mealybugs per plant. Plants were then taken out of the pots and the soil was removed and whole plants were treated at 120° F for 15 min and 125° F for 15 min on 4 April 2005. The plants were then potted and placed under mist. Plants were examined one time on 14 May and number of mealybugs counts. The mealybug hide between the leaf roles and since this was destructive sampling only one sampling could be taken. The treatments of 120° F for 15 min gave above 99% level of control of miscanthus mealybug. The 125° F also worked with no damage to the plants but a grower really only needs to reach the 120° F temperature to control this pest (Table 3).

Chinese Holly: Cottony Taxus/Camellia Scale, *Pulvinaria floccifera*, Control. Ten branch samples were treated at 120° F for 15 min and 10 untreated controls were compared. Post counts of hot water treated plants gave 99% or above level of control of this scale (Table 3).

Table 3. Summary of trials results conducted by University of Maryland.

Insect (treated with hot water)	Temperature	Time (min) to obtained > 99% mortality
Boxwood mites	49 °C (120 °F)	15
Miscanthus mealybug	49 °C (120 °F) * can tolerant 51 °C (125 °F)	15
Cottony taxus/camellia scale	49 °C (120 °F)	15
Fern scale	49 °C (120 °F)	15

WHERE DO WE GO FROM HERE?

We believe the potential for using hot water treatments for reducing certain ornamental pests is strong. It may not control all pests, and some plants may be sensitive to the temperatures needed to kill a particular pest but this can be established by continued research on temperature tolerance of additional species of plants. We conducted trials on a couple of herb species and found that plants such as tarragon could not withstand temperatures above 110 °F and basically cooked the cuttings at this temperature. Sage only tolerated temperatures up to 112°F, and rosemary could take 120° F but for just 10 min. Growers are not likely to kill many pests at this lower temperature and shorter treatment intervals. This is too bad since there are only a very limited number of labeled chemical options for growers to use on herb crops. On the bright side we found that New Guinea impatiens cuttings are very tolerant of 120° F treatments for up to 20 min. A major pest group that damages New Guinea impatiens is broad and cyclamen mites. Other researchers have reported that treatment with hot water at 112° F for 10–12 min kill cyclamen mites.

We plan to continue our work at the University of Maryland and expand the list of species of plants tested to establish whether they can tolerate 120° F temperature treatments and for what length of time. We believe we have a machine that is fairly economical to build and fairly user friendly with a little practice.

We will be publishing a two-part fact sheet in early 2007 that explains how to build and operate the hot water immersion system.

Until then we will try to keep the heat up on the pest, at least at the propagation stage.

Acknowledgements: Funding for the project: Special thanks to the Maryland Nursery and Landscape Association for providing 2 years of financial support to build a portable hot water immersion re-circulation system. Thanks also to USDA CREES IPM program and the Virginia Nursery Association for providing funding for conducting the trials in the 2nd year of this project. To fund this project we have obtained $3,100 from the Maryland Nursery and Landscape Association, $1,100 from the Virginia Nursery Association and $9,300 from USDA CREES IPM program to conduct trial with nurseries in 2005.