Development and Implementation of Non-toxic Pest Control System for Shipping Ornamental Plant Commodities: Demonstrating the Economic and Environmental Benefits of Hot-water Pest Eradication

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Nursery crop and flower production is the major agricultural commodity in San Diego County with a value of over $1.2B in 2017. Many of these products are shipped out of the county but no matter how vigilant we are in detecting new and potentially damaging pests, there are still a small number that get through and impact our agricultural commodities. These pests not only reduce the quality and amount of marketable plants and flowers but also can add an additional burden to the growers, the environment, and health and safety of the workers by increasing the use of pesticides to manage the pests. A survey in San Diego County showed that from July to December 2014, 6,589 pots of varying sizes and plant types had to be destroyed due to invasive scale and mealybug species infestations (retail value of $232,000).

Hot water treatment of plant material for the elimination of endemic and invasive pests is not a new concept and it is widely used in Hawaii. In other states, the preferred methods for eradication nursery pests are pesticide applications or plant destruction, which pose undue economic burden on the producer. This project is a demonstration of the development and test of the use of a hot water system to eradicate selected nursery pests.

We used a prototype system that can deliver a hot water "shower" to plants in an enclosed insulated trailer. The hot water system consists of a metal shipping container on a trailer with two water tanks (hot and cold) and 2 propane tankless hot water heaters. Heated water is pumped into the shipping container and applied to potted plants through spray nozzles located on pipes mounted on the walls and ceiling. The floor of the trailer is slanted to allow all water to drain out. Working with engineering professors at UC Merced to refine the electrical and physical components of the system, we tested the system on a spectrum of nursery crops and pests to determine appropriate time and temperatures to control the pests but not injure the crops.

A video illustrating the improved chamber and spraying system is downloadable at:
https://ucmerced.box.com/s/51bhk5c7756ykqoe104wulo9sou380xt

A new software program (source available at: https://github.com/rajk1344/PlantSense) was developed by the team at UC Merced to record the temperature in multiple points inside the spray chamber during applications, to monitor and visualize it during applications, and to later analyze it.

A video was made showing the parts, process and operation of a hot water treatment. This video was made on April 14, 2020 and can found at:
https://ucanr.edu/sites/floriculturenursery/Treating_Plants_with_Hot_Water_for_Pest_Control/

Demonstrate Efficacy on a Spectrum of Nursery Crops and Pests

Three trials were conducted during the duration of the grant period. Three of tests were strictly temperature effect studies while the fourth was used to test the effect of hot water temperature on English ivy and spider mites. Unfortunately, the temperature required to kill the mites (113.65°F for 8 minutes) was excessively damaging to the ivy, preventing an accurate assessment of efficacy against the mites.

Test 1: Plants were sprayed with water that averaged 113.82° F for 8 minutes, cooled down to average 80.85° F in 7 minutes. Plants were stored outside to dry for ~ 1 hour at ~ 68 F. The planted were stored in Quonset afterwards and evaluated 3 days later.

Species with no or acceptable injury	**Injury score after 3 days (1=none, 10=severe)**
Jade sp. *Crassula ovata*	1
Aloe hybrid c.v. "minnie belle'	1
Rainbow elephant bush *Portulacaria afra* 'Variegata'	1
Kalanchoe Hildebrandtii	1
Golden Sedum sp. *Sedum adolphi*	1
Cotyledon hybrid c.v. 'Mint Truffles'	1
Society Garlic sp. *Tulbagbia violacea*	2
Japanese Boxwood Buxus microphylla var. japonica	2
Species with unacceptable injury	
Freesia sp. Freesia lactea	3
Polka Dot Plant *Hypoestes spp* (pony pack).	4
Cape Daisy sp. *Euryops pectinatus*	6
Geranium Pelargonuim hortorum 'Zonal geranium white'	7
Autumn Sage sp. *Salvia greggii*	8

Test 2: Guzmania sp. Deseo Yellow G26 were exposed to 1) water at 119.5°F for 7 minutes followed by 'cold' (80°F) water for 6 min to cool down to average 90.36° F, 2) water at 113°F for 6 minutes followed by 'cold' (82.4°F) water for 6 min to cool down to 88.23° F, or 3) water at 82.42 F for 10 minutes.

All plants were moved outside to dry for ~ 1 hour at ~ 78 F and then placed in the greenhouse for 3 days.

Water temperature	Injury score after 3 days (1=none, 10=severe)
119.5F	8
113F	3
82F	2

Test 3: Plants were exposed to hot water at 117.1° F for 8 minutes followed by 'cold' water 82.9° F for 5 minutes to cool down.

All plants were moved outside to dry for ~ 1 hour at ~ 68 F and then placed in the Quonset for 3 days.

Species with no or acceptable injury	Injury score after 3 days (1=none, 10=severe)
Mandevilla cv. Pink Blush	1
Species with unacceptable injury	
Kalanchoe Crasslaceae spp. Pink Flowers	3
Kalanchoe Crasslaceae spp. Orange Flowers	3
Autumn Sage sp. *Salvia greggii*	8
PT *Begonia* spp	9

Temperature Threshold Summary:
From the three tests that were conducted, the following is a rank of plants/species that tolerated the highest temperatures in descending order:

Able to tolerate up to 117.2°F for 8 minutes are: Mandevilla c.v. 'pink blush', Jade spp., Japanese boxwood, Society garlic, Aloes, elephant bush, cotyledon hybrid c.v. 'mint truffles', and *Kalanchoe Hildebrandtii*.

At 113.8°F, the following plants showed mild damage: Fresia spp., Guzmania spp., Golden Sedum, and Kalanchoe spp.

The following species need to be treated below 113°F: Cape Daisy, Geranium 'Zonal geranium white', Autumn Sage, Hypoestes spp., Begonia, and English ivy. Further testing on the last group needs to be conducted to determine their temperature threshold.

Conclusions:
These studies show that tolerance to hot water above 113F varies by species and likely by cultivars within a species. Based on the single test where a pest was present on a plant species, it is also clear that this system will only be feasible where plants are able to tolerate temperatures above 117F, even if cooled down immediately after exposed to the hot water. Future work should be based on determining which plant species can tolerate being exposed to hot water about 117F as well as determining the lethal time and temperatures for arthropod pests and possibly mollusks.

Thanks to Altman Plants in Vista California for the generously allowing the use of electricity, water, plants, and space to conduct these tests.