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

One Time Funding Request for UCCE, San Diego
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The Problem Affecting San Diego

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 and frequently out of state or even out of the country. However, because of the increasing movement of people, plants, and even household goods around the world and the proximity of San Diego to the Mexican border and a shipping port, 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. Although plants treated in this manner in Hawaii meet phytosanitary requirements in California, hot water treatment of ornamental plants are not practiced in other states. The preferred methods for eradication of arriving invasive or nursery cleanliness standards are pesticide applications or plant destruction, which pose undue economic burden on the producer.

Our Proposal to Address the Problem

We have acquired 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. We will be working with engineering professors at UC Merced to refine the electrical and physical components of the system. Once that is completed, we will test the system on a spectrum of nursery crops and pests (e.g. millipedes, mites, snails, mealy bugs, et al.) to determine appropriate time and temperatures to control the pests but not injure the crops.

The overall objective is to demonstrate that this method can be employed in San Diego and all of California and then the technology can be expanded for other states to use in lieu of pesticide applications and plant destruction. Specific objectives are: 1. Reduce the nursery product losses incurred due to endemic and invasive pests; and, 2. Reduce the pesticide load deposited in the environment. The proposed work will document the effectiveness of this new tool and the economic and environmental benefits.

We need to make the prototype more reliable to demonstrate to growers and regulators that it is a viable method of controlling regulated and other pests in order for this non-toxic method of pest control adoption to occur, which is why we'll be working with the engineering professors at UC Merced. This includes developing a system to regulate the temperature of the water, adding a recirculating water system to reduce the cost of the operation and conserver water, and refining the treatment area layout to improve the efficacy of the treatments.

The development and testing of this system is a critical step in supporting the viability of the ornamental crop industry in San Diego County and, at the same time, contributing to the protection of water quality and the workers. We will work and collaborate with established connections including but not limited to the San Diego County Farm Bureau, San Diego County Flower and Plant Association, and County of San Diego Department of Agriculture, Weights and Measures.

The successful outcome of this project will result in a system that growers observe or build for use on their own site or even be a potential opportunity for a company to develop a commercial product. When adopted the impact will be:
1) A reduction in pesticide purchase and application;
2) Reduced insecticide resistance development due to fewer treatment applications and shorter application intervals;
3) Reduced regulatory holds on plants or on mandatory plant destruction by providing an alternative method of eradication and allowing regulators to verify the effectiveness.

Project Scope:
• Improve and verify the reliability of the hot water system prototype
• Demonstrate efficacy on a spectrum of nursery crops and pests
• Conduct an in-field workshop with growers
• Create a final report and deliver to key stakeholders

Improve and verify the reliability of the hot water system prototype

Prior to this one-time funding grant, reliability of the system was jeopardized by the performance of the water pump. Initially, two pumps were purchased, Goulds ¾ and 1 ½ hp centrifugal pumps. When operated, the both pumps tripped the internal thermal overload circuit after approximately five minutes of use. After contacting a specialist, the pump was replaced with a Dayton 240 VAC 3 hp self-priming pump. Of the numerous start-ups and three temperature trials, this pump performed flawlessly.

The electrical power was also improved. Prior to this grant, a gasoline powered generator was used for all power needs: this required to be run continuously to ensure the continuous operation of sensors, computers and, and water heaters. We added a battery and inverter to support the continuous low wattage requirements of all electronics, so that the generator could be turned on only at the time of the operation of pump. Another improvement was addition of a 20 amp power strip. Prior to this, the pump was turned on and shut off by manually removing the plug from the generator. The power strip allowed for the pump to be controlled by a single on/off switch

The cold water storage tank (300 gallon chemical tote) had to be replaced due to cracks and leaking. A local farm supply store donated an extra tank to replace it.

The interior of the spray chamber was modified with the addition of plywood to provide interior insulation. The insulation allowed for the temperature to rise to the specified target more quickly and hold the desired temperature more precisely and evenly.

A drop-down nozzle assembly was previously installed in the chamber from the ceiling. This system was designed to lower to the floor in the event of smaller plants being treated. The premise being that less heat would be lost if the plants were closer to the nozzles. It was cumbersome and had trouble with the assembly to lower parallel to the floor. It was removed and replaced with a non-mobile structure attached to the ceiling of the spray chamber.

The inside of the chamber, and the nozzles were replaced, and adjusted or capped in order to have three areas with different exposure to water: ambient, spray, drench. Plants in the “spray” area would be sprayed hot water from multiple directions. Plants in the “drench” are would be showered water from a nozzle above. Plants in the “ambient” area would not receive any direct water, rather immersed in humidity with the desired temperature.

In total, 36 of the original 65 nozzles were capped to decrease the gallons per minute of water used.

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. Unfortunately, the final program was developed at the conclusion of the time period and not fully tested.

Demonstrate Efficacy on a Spectrum of Nursery Crops and Pests

Four trials were conducted during the duration of the grant period. Three of tests were strictly temperature effect studies while the fourth was an attempt to study two-spotted spider mites on English Ivy. Unfortunately, the temperature achieved to kill the mites also damaged the ivy to prevent an accurate assessment of efficacy against the mites. The ivy was exposed to an average of 113.65°F for 8 minutes. The following are summaries of the three temperature effect studies.

Hot water treatment 4/14/2020

Treatments: 1) Hot water followed by 'cold' water cool down, 2) 'Cold' water only

<u>Number plants per treatment/Species tested</u>

6 Jade sp. *Crassula ovata*

2 Aloe hybrid c.v. "minnie belle'

2 Rainbow elephant bush *Portulacaria afra* 'Variegata'

2 *Kilachoe Hildebrandtii*

2 Golden Sedom sp. *Sedom adolphi*

2 Cotyledon hybrid c.v. 'Mint Truffles'

4 Society Garlic sp. *Tulbagbia violacea*

8 (pony pack) Polka Dot Plant *Hypoestes spp.*

6 Autumn Sage sp. *Salvia greggii*

4 Freesia sp. *Freesia lactea*

4 Geranium *Pelargonuim hortorum* 'Zonal geranium white'

4 Cape Daisy sp. *Euryops pectinatus*

4 Japanese Boxwood *Buxus microphylla* var. japonica

Trial specific data

Plants were put in chamber at 10:40 am. It took 3 minutes to reach target temperature. The plants were exposed to average of 113.82° F for 8 minutes (measured at soil level of plants). The cooling phase brought 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 (4/17/20). Trays with orange flagging are the ones exposed to the hot water. Non marked trays exposed to 71.33° F water for 8 minutes. No pests were present for this test; temperature tolerance only.

Pre treatment (4/14/2020)

Post treatment (3 days after treatment)

Jade

Injury score: 1 (1=none, 10=severe)

Boxwood

Injury score: 2

Daisy

Injury score: 6

Pre treatment (4/14/2020)

Post treatment (4/17/2020)

Hypoestes

Injury score: 4

Succulent spp.

Injury score (all spp.): 1

Geraniums

Injury score: 7

Pre treatment

Post treatment

Freesia

Injury score: 3

Sage

Injury score: 8

Society garlic

Injury score: 2

Hot water treatment 4/27/2020

Treatments: 1) Hot water (119.5°F) followed by 'cold' (80°F) water cool down, 2) Hot water (113°F) followed by 'cold' water cool down, 3) 'Cold' water only

<u>Number plants per treatment/Species tested</u>

14 plants Guzmania sp. Deseo Yellow G26

Trial specific data

Treatment 1 - Plants put in chamber at 10:50 am. It took 1 minutes to reach target temperature. Exposed to average of 119.5° F for 7 minutes (measured at soil level of plants). Brought down to average 90.36° F in 6 minutes. Plants stored outside to dry for ~ 1 hour at ~ 78 F. Stored in the greenhouse afterwards. Evaluation 3 days later (4/30/20). No pests were present for this test; temperature tolerance only.

Treatment 2 - Plants put in chamber at 10:20 am. It took 1 minutes to reach target temperature. Exposed to average of 113° F for 6 minutes (measured at soil level of plants). Brought down to average 88.23° F in 6 minutes. Plants stored outside to dry for ~ 1 hour at ~ 78 F. Stored in the greenhouse afterwards. Evaluation 3 days later (4/30/20). No pests were present for this test; temperature tolerance only.

Treatment 3 – Plants put in the chamber at 10:41 a.m. Exposed to an average of 82.42 F for 10 minutes. Plants stored outside to dry for ~ 1 hour at ~ 78 F. Stored in the greenhouse afterwards. Evaluation 3 days later (4/30/20). No pests were present for this test; temperature tolerance only.

Post treatment (4/30/2020, 3 DAT)

Hot water @ 119.5 Injury score: 8 (1 = none, 10 = severe)

Hot water @ 113 Injury Score: 3

Untreated Control @ 82.4F Injury score: 2

Hot water treatment 6/3/2020

Treatments: 1) Hot water followed by 'cold' water cool down, 2) 'Cold' water only

Number plants per treatment/Species tested

5 Kalanchoe *Crasslaceae* spp. Pink Flowers

5 Kalanchoe Crasslaceae spp. Orange Flowers

8 Autumn Sage sp. *Salvia greggii*

8 PT *Begonia* spp.

6 Mandevilla cv. Pink Blush

Trial specific data

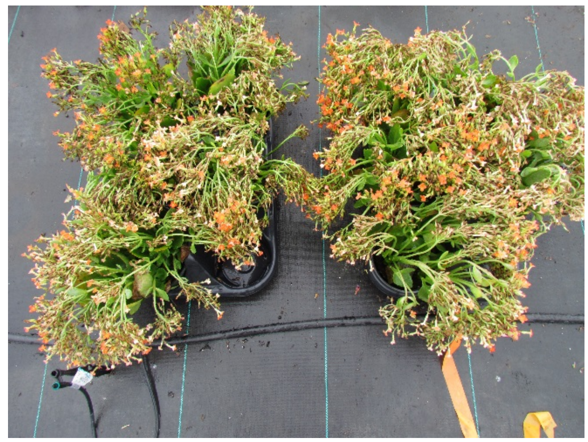
Plants put in chamber at 9:54 am. Took 2 minutes to reach target temperature. Exposed to average of 117.1° F for 8 minutes (measured at soil level of plants). Brought down to average 82.9° F in 5 minutes. Plants stored outside to dry for ~ 1 hour at ~ 68 F. Stored in Quonset afterwards. Evaluation 3 days later (4/17/20). Trays with orange flagging are the ones exposed to the hot water. Non marked trays exposed to 78.03° F water for 14 minutes. No pests were present for this test; temperature tolerance only.

Pre treatment (6/3/2020)

Post treatment (6/5/2020)

Kalanchoe spp. Pink flowers

Injury score: 3



Kalanchoe spp. Orange flowers

Injury score: 3

PT *Begonia* spp.

Injury score: 9

Pre treatment (6/3/2020)

Mandevilla

Autumn Sage

Post treatment (6/5/2020)

Injury score: 1

Injury score: 8

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.

Further tests were not conducted due to depletion of funds.

Due to the restrictions placed for COVID exposure and the rarity of large-scale pest outbreaks among nursery growers, a comparison between chemical applications and hot water treatment was not accomplished.

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. **Conclusions:**
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Conduct an In-field Workshop with Growers

Due to the restrictions placed by the State of California and San Diego County from the COVID-19 pandemic, a public demonstration of the unit had to be suspended. In its place, 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/

Create a Final Report and Deliver to Key Stakeholders

This report is available for agency and public record. The summary with links to this final report for key stakeholders is available on the Floriculture and Nursery Section of the San Diego Cooperative Extension website (cesandiego.ucanr.edu).

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