SCIENTIFIC NOTE

Potential for Metabolic Stress Disinfection and Disinfestation (MSDD) Treatment to Disinfest Commodities of White Peach Scale and other Surface Pests

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Abstract. Metabolic stress disinfection and disinfestation (MSDD) is a postharvest treatment that combines short periods of low pressure (vacuum) and elevated CO_2 with ethanol vapor to control pathogens and arthropod pests on commodities. The system was tested against white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Homoptera: Diaspididae), a serious pest of papaya in Hawaii. Treatment with low pressure (125 mm Hg) and high CO_2 (>99%) alone had no effect on mortality of second stage nymphs, whereas a combination of low pressure, high CO_2 and ethanol vapor (75 mg l^{-1}) killed 98% of the individuals tested. This combination treatment has potential to disinfest fresh commodities of surface pests.

Key words: *Pseudaulacaspis pentagona*, quarantine treatment, postharvest treatment, low pressure, vacuum, ethanol, controlled atmosphere

Introduction

The importation of fresh horticultural commodities from Hawaii into the continental U.S. is prevented by regulations unless they are free of any quarantine pests. Many fruits and vegetables exported from Hawaii receive a postharvest disinfestation treatment to control fruit flies and various surface pests (Follett 2004). White peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Homoptera: Diaspididae) is a serious pest of papaya that causes an increase in production costs, decreases in crop yield, and restrictions on fruit exports, especially to California and Japan (Follett 2000). Vapor heat and irradiation are effective quarantine treatments against white peach scale (Follett 2006), but other technologies have potential and may have advantages in terms of cost and maintenance of commodity quality. Lagunes-Solar et al. (2006) designed and tested a system called metabolic stress disinfection and disinfestation (MSDD) that combines short cycles of low pressure (vacuum) and high CO_2 with ethanol vapor to control pathogens and arthropod pests on commodities. Recent tests with Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), oriental fruit fly, *Bactrocera dorsalis* (Hendel), and melon fly, *Bactrocera cucurbitae* (Coquillett) life stages in papaya fruit showed low mortality, suggesting this treatment might not be effective against internal-feeding pests (Arevalo-Galarza and Follett, in press). We conducted a test with white peach scale to determine if the treatment conditions that were ineffective against fruit flies in fruit might be effective against a representative external feeding pest.

Materials and Methods

The MSDD system used in tests was constructed by the Crocker Nuclear Laboratory, University of California, Davis, and is nearly identical to the system described in Lagunes-Solar et al. (2006). The apparatus consists of a plexiglas vacuum chamber (23 x 58 x 28 cm, 41.6 l); a mechanical, twin-cylinder, oil-less vacuum pump (Model 71R645-C114-D303X, GAST Manufacturing, Benton Harbor, MI); an ethanol peristaltic pump (Mini-Pump Variable Flow, Fisher Scientific, Pittsburg, PA); and a programmable logic controller (PLC, Model Easy 619-DC-RC, Moeller Electric, Franklin, MA). The vacuum pump is fitted to a gas CO_2 cylinder which was used to create a rapid adiabatic expansion of volatile chemicals within the chamber. The MSDD system is also fitted with pressure gauges (G type, Precision Pressure Gauges, Chino, CA) and pressure transducers (Model PN 142PC15D, Honeywell International, Morristown, NJ) for remote monitoring (Digital Multimeter Model 160B, Keithly Instruments, Cleveland, OH), and temperature sensors (Digisense Temperature Controller, Cole Parmer Instruments, Chicago, IL). For MSDD treatment, the commodity or sample was introduced inside the chamber and the system closed for operation.

The MSDD treatment consists of a series of five rapid decompression (vacuum) and compression cycles. The pressure was first lowered from 760 mm Hg to 125 mm Hg during 10 seconds; the pressure was maintained at 125 mm Hg for approximately 10 seconds, and then increased by the addition of CO_2 (99.98%) to 760 mm Hg again, which required about 40 seconds, where it remained for about one minute before repeating the cycle. Once the five cycles are completed, the chamber was evacuated once more to establish the low pressure environment (125 in Hg), and ethanol (75 mg l^{-1}) was injected and held for 1 h. In each experimental replicate, the MSDD treatment was applied twice in succession to the test insects. The ethanol injection was omitted in some tests to separate the effect on insect mortality of the compression and decompression cycles and ethanol vapor. The concentration of ethanol used (75 mg l^{-1}) was the mean reported by Lagunas-Solar et al. (2006). Untreated control insects were held to estimate natural mortality.

Crawler stage white peach scales were collected from papaya trunks and transferred using a camel hair brush onto butternut squash in the laboratory. Cohorts of crawlers were collected and set up on three different dates which served as replicates. Once crawlers had settled and molted, the second stage nymphs were used in tests. The number of scales on each squash was standardized at 100 by removing excess individuals before treatment. Three infested squashes were used on each test date: one infested squash was treated with low pressure alone, the second squash was treated with low pressure and ethanol vapor, and the third was left untreated as a control. Mortality was determined after 10 days by examining scale size: scales surviving the treatment had molted to the adult stage, which was significantly larger in size than the second stage nymph. In cases where body size changes were not definitive, the scale was turned over to examine the body under the covering; dead scales were brown and shriveled, whereas live scales were orange and turgid. Mortality data were evaluated using nonparametric rank scores test for three treatment levels (Kruskal-Wallis test reported as a chi-square approximation) to compare the effects of low pressure, low pressure plus ethanol vapor, and no treatment (SAS Institute 2002).

Results

No white peach scales died in the low pressure only and control treatments, whereas a significantly higher 98% of individuals died in the low pressure plus ethanol vapor treatment (Table 1) ($\chi^2 = 7.7$, df = 2, P = 0.02). Applying a series of decompression and compression cycles did not cause any mortality unless followed by ethanol vapor, suggesting that the ethanol vapor was the lethal component of the MSDD treatment.

Table 1. Percentage mortality of second stage nymphs of white peach scale 10 d after MSDD treatment with and without ethanol.

Replicate	No. insects	Control	MSDD treatment	
			No ethanol	With ethanol [a]
1	100	0.0	0.0	100.0
2	100	0.0	0.0	97.0
3	100	0.0	0.0	97.0

[a] Significant treatment effect by Kruskal-Wallis test ($P<0.05$)

Discussion

Low pressure has been studied as a disinfestation treatment mostly for stored products pests (Burg 2004). Insect mortality during low pressure treatment is believed to be a result of low O_2 concentration affecting critical metabolic functions rather than any direct physical effects on the insect (Navarro and Calderon 1979). Low oxygen in combination with high CO_2 causes death by asphyxiation or carbonic acid build-up in insects (Neven 2003). Ethanol vapor treatment alone has been shown to cause high mortality in light brown apple moth, *Epiphyas postvittana*, larvae in apples (Dentener et al. 2000, Jamieson et al. 2003) and two spotted spider mite (Dentener et al. 1998). Lagunes-Solar et al. (2006) reported high mortality of various life stages of *Drosophila melanogaster, Heliothis virescens, Frankliniella occidentalis, Myzus persicae, Tetranychus urticae* and *Amblyseius cucumeris* exposed in Petri dishes to MSDD treatment; when low pressure plus ethanol was used, insects were killed in 0.4–2 h, but treatment with low pressure alone required 6–12 h for high mortality. In experiments with tephritid fruit fly eggs and larvae, mortality was high when insects were exposed to MSDD (low pressure [125 mm Hg] and ethanol vapor [75 mg l^{-1}]) in Petri dishes, but mortality was significantly lower when these life stages were treated inside papaya fruit (Arevalo-Galarza and Follett, in press). This suggests generally that exposure to ethanol vapor is lethal to insects, but that insects are somewhat tolerant of low pressure treatment (see also Mitcham et al. 2006). Internal-feeding insects in fruit may be protected from the toxic effects of ethanol treatment because the vapor does not easily penetrate the pericarp and pulp. Whereas MSDD treatment may not be practical for many internal feeding pests such as tephritid fruit flies, it has potential to disinfest commodities with surface pests such as scales, mealybugs, thrips, aphids and mites.

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