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Efficacy evaluation of horticultural oil based thermotherapy for pear psylla management

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ABSTRACT

The goal of this study was to improve techniques for pear psylla, *Cacopsylla pyricola* (Föerster) control, one of the major pests in pear orchards worldwide and in the United States. Mortality of adult pear psylla was determined after its exposure to horticultural oil (HO) combined with high temperature (thermotherapy) treatments. A laboratory–scale application technology unit was developed to apply HO–based thermotherapy. Spray treatments included four variables namely heat–condition (i.e., heat and no–heat), HO concentration (i.e., 0.5 and 1.0%), nozzle types (i.e., N1: Conejet nozzle, N2: D2/DC13 disc–core nozzle) and application pressure (i.e., 344.7 [50] and 689.5 [100] kPa [psi]). Each treatment was replicated four times on pear psylla bioassays. Mortality was evaluated at 3, 6, 12, 24 and 48 h after spray application. HO combined with thermotherapy achieved as high as 100% pear psylla mortality during early hours after spray application. The overall mean pear psylla mortality using HO under heat condition (63.7 ± 2.4% [mean ± std. error]) was significantly higher compared to no–heat condition (43.6 ± 1.8%). Higher HO concentration (i.e., 1.0%) under heat condition had significantly higher mortality (60.2 ± 2.3%) compared to similar applications at lower concentration (47.1 ± 2.0%). Pear psylla mortality was significantly affected by nozzle type under heat conditions, and nozzle N1 (with comparatively higher spray coverage on water sensitive papers) had significantly higher (74.4 ± 3.1%) pear psylla mortality compared to nozzle N2 (52.9 ± 3.3%). The interaction between thermotherapy and each of the HO concentrations and nozzles on psylla mortality was significant at $\alpha = 0.05$. Overall, HO combined with thermotherapy caused a rapid kill of pear psylla. Future field studies are warranted to evaluate efficacy of HO–based thermotherapy at reduced HO concentrations and pertinent effects on smothering of eggs and pear psylla mortality.

1. Introduction

Pear, *Pyrus communis* L. (Rosaceae), is a high value specialty crop in the Pacific Northwest region of the United States. About 73.7% of the total US pear production in 2017 was from Washington and Oregon states (USDA-NASS, 2017). Pear trees are susceptible to stunted growth, leaf necrosis, wilting, defoliation, fruit drop, and yield reduction. These injuries are caused by pear psylla, *Cacopsylla pyricola* (Föerster), directly impacting fruit quality from russeting and sticky secretions, as well as being the vector for a mycoplasma that causes pear decline (Horton, 1999; Bell, 2015; Cooper and Horton, 2017). Pear psylla is one of the most challenging insect pests in Washington, USA and its control is a major challenge for integrated pest management (WSU Tree Fruit, 2017). Management is difficult mainly due to the psylla's development of pesticide resistance to synthetic chemicals (Follett et al., 1985; Pree et al., 1990; WSU Tree Fruit Research and Extension Center, 2001). Moreover, use of chemicals could reduce effectiveness of pear psylla's natural enemies in the orchard environment. Other biological reasons including pear psylla's long–life cycle, overwintering biology and high mobility in the orchards also affects the management (Horton, 1999).

Therefore, there is an increasing demand to develop and implement new pest management techniques to control pear psylla. For decades, horticultural oils (HO) have been used in both organic and conventional tree fruit production management (Johnson, 1985; Alam et al., 2017). HOs can suffocate insects and their eggs by preventing gas exchange, which leads to increased mortality (Wins–Purdy et al., 2009). It has also been reported that insect and mites cannot develop resistance to HO (Larew and Locke, 1990; Wins–Purdy et al., 2009). In various literature,

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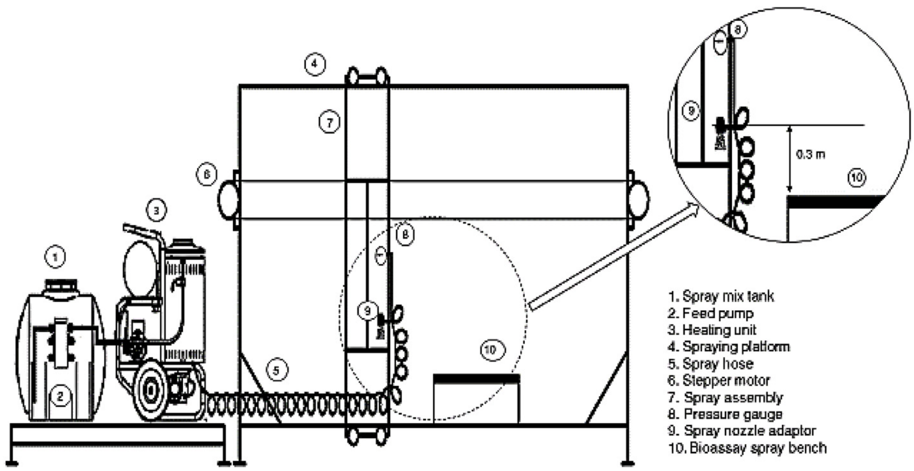

Fig. 1. Schematics of the thermotherapy application system.

HOs have also been referred to as dormant oil, mineral oil, summer oil, vegetable oil and essential oil. The first use of HO was restricted only to the dormant phase of trees, but recent developments in terms of extraction and oil refining have made it appropriate for foliar applications (Wins–Purdy et al., 2009). Essential oils, a type of HO which can be obtained by steam distillation of aromatic herbaceous foliage, have demonstrated protection potentials against insects (Batish et al., 2008; Nerio et al., 2010). Essential oils have been investigated in many studies as an alternative to synthetic pesticides (Weidhaas, 1988). Yang et al. (2010) studied the contact toxicity effects of essential oils derived from garden thyme, *Thymus vulgaris* L. (Lamiaceae), patchouli, *Pogostemon cablin* (Blanco) Benth. (Lamiaceae), and lemon–scent gum *Corymbia citriodora* (Hook.) K.D.Hill & L.A.S.Johnson (Myrtaceae), on immature and adult sweet potato whitefly *Bemisia tabaci* (Gennadius) biotype B *Bemisia argentifolii* (Bellows & Perring). The study reported that thyme oil resulted in 58.2–73.4% decrease in the survival rate of the whitefly compared to the control.

Heat treatment or thermotherapy, as a treatment for plant disease, has been used for a long time and has been reported as an effective method to prevent numerous diseases caused by viral infections in tree fruits (Hoffman et al., 2013). Thermotherapy, for pathogen control, can be defined as treating infected plants with heat to kill a pathogen, with minimal to no damage to the plants (Grondeau et al., 1994). Thermotherapy treatments can be implemented through different methods such as soaking the treated material in hot water or hot solution (hot bath), hot air, using vaporized water or vaporized solution and with the use of microwave energy. Also, insect pest infested trees could be exposed to extra solar radiation by adding reflecting materials on the ground between the tree rows (Doud et al., 2017). The mechanism of thermal pest control was assumed to be due to the insect's cell wall damage and may depend on the total temperature acclimation (Hansen et al., 2011). Thermotherapy has been widely used in seed and nursery stocks disease management (Eranthodi et al., 2010). The first use of vapor–based heat treatment in fruits and vegetables was reported in 1913, while hot water was used for the first time in 1925 (Hansen et al., 2011). Neven (2005) studied a combination of short–duration high temperatures under a controlled atmospheric environment (low oxygen and elevated carbon dioxide) to control codling moth, *Cydia pomonella* (Linnaeus), in sweet cherries *Prunus avium* (L.). The study used chamber temperatures of 45 °C for 45 min, and of 47 °C for 25 min under controlled environments (1.0% O_2, 15.0% CO_2, -2 °C dew point), with both treatments resulting in 100% mortality of codling moth. Yahia and Ortega–Zaleta (2000) used 21 treatments of high temperature air in controlled atmosphere to study the in–vitro mortality of eggs and third instar larvae of Mexican and West Indian fruit fly fruit flies, *Anastrepha ludens* (Loew) and *A. obliqua* (L.). The researchers concluded that hot air at ≥44 °C and 50.0% RH in controlled atmospheric environment (0 kPa O_2 + 50 kPa CO_2) for 160 min increased the mortality of *A. ludens and A. obliqua* eggs and third instar larvae.

To the best of our knowledge, there is no prior study that used thermotherapy to control insects in orchard condition, besides our collaborative on–going work with the University of Florida, where it has been experimented to reduce citrus greening inoculum (*Candidatus Liberibacter asiaticus*) in tree canopies (Ehsani et al., 2013). Several studies have evaluated the combined use of HO and conventional pesticides on insect mortality (Leong et al., 2012; MacKenzie et al., 2017). However, the advantages of HOs in combination with thermotherapy have not been investigated. Such combinations may magnify the thermotherapy effect by volatilization of HOs due to heat, making it more potent. It could improve efficacy by eliminating insect pests irrespective of their life–cycle, growth stage and may help in controlling the related pathogenic diseases. Considering the potential of HO–based thermotherapy in tree-fruit crop pest management, the overall goal of this study was to assess the feasibility of HO–based thermotherapy as a control strategy for pear psylla. The specific objectives were to a) develop a custom thermotherapy application unit to evaluate the efficacy of HO–based thermotherapy for pear psylla management, and b) study the effect of varied horticultural oil concentrations in combination with thermotherapy and application methodology (sprayer nozzle type and operating pressure) on pear psylla mortality.

2. Materials and methods

The experiments were conducted at the Center for Precision and Automated Agricultural Systems (CPAAS), Washington State University, Prosser, WA during the summer of 2017. Tested were four replicates (bioassays), with five adult psylla in a bioassay, for each treatment. All the tests were conducted under ambient laboratory conditions at around 25 °C. Following sections describe pertinent methods associated with the experiment.

2.1. Thermotherapy application system development

A laboratory–scale spray application system was designed and developed to produce chemical application characteristics similar to the technology used in pear orchards. Such system was then used to apply the thermotherapy treatments (Fig. 1). The system consisted of a movable spray assembly (0.4 × 1.9 m) made of t–slotted aluminum framing mounted on t–slotted aluminum platform (0.6 m wide × 3.6 m long × 1.8 m high). The spray assembly moved back and forth on a set of four track rollers. The spray assembly was driven by a stepper motor (Model: ARM98AC–N10, AR series, Oriental Motor Co., Ltd., Japan)