POTENTIAL FOR MANAGING *PRIONUS CALIFORNICUS* IN HOP USING MATING DISRUPTION

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Introduction

The longhorned beetle, *Prionus californicus* Mots. Is economically important pest of hop, *Humulus lupulus,* in the northwestern U.S. (Bishop et al. 1984).

Adult beetles emerge during late June or early July and are active during evenings through late-August. They are among the largest beetles in North America, ranging in body length from 1 to 2 inches.

Adults do not feed and probably live less than three weeks in the field. Once mated, the adult females lay eggs in soil near the bases of hop plants. The larvae feed on plant roots, requiring 3-5 yr to complete development. Mature larvae often exceed 2.5 inches in length. Feeding damage to hop roots results in decreased nutrient uptake, water stress, and reduced growth rate and can cause wilting and death of the entire plant.

Current management of *P. californicus* in hops involves both cultural and insecticidal control. Cultural control entails removing the crowns and roots of hop plants from heavily infested fields in the fall. The fields then can be fallowed for 2-3 years before replanting, or the soil can be fumigated and the fields replanted the following spring. Both options are expensive (~ $700 per acre; Hinman 2004). Fallowing leads to an additional loss of revenue because the trellis system upon which hops are grown limits the opportunity to produce an alternative crop and removing and subsequently replacing the trellis system is costly (~2,000 per acre).

The organo-phosphate soil insecticide ethoprop is labeled for managing *P. californicus* in hop, but its use is hindered by label restrictions and is considered a potential threat to wildlife (Patterson 2003) and to the health of farm workers (Ames and Stratton 1991) by the Environmental Protection Agency. Thus, there is a need for new management tactics for *P. californicus* in hop.

Our research has shown that female *P. californicus* produce a volatile sex pheromone, (3R,5S)-3, 5-dimethlydodecanoic acid (Cervantes et al. 2006, Barbour et al. 2006, Rodstein et al. 2009, 2011) that strongly attracts males. Sex pheromones have been effectively used to manage insect pests by hindering mating, either by mass trapping (removing males from the population) or by mating disruption (inundating the habitat with synthetic pheromone such that males cannot locate mates; Millar 2007, Witzgall et al. 2010).

Here, we summarize small plot experiments using our research lures and large plot experiments using commercial pheromone dispensers evaluating the potential for managing *P. californicus* in hop yards using mating disruption.

Objectives and Hypotheses

- Our experiments tested the hypothesis that mating disruption of male *P. californicus*, by release of synthetic pheromone into the environment using relatively high-dose lures, will reduce the number of males that can locate (and, therefore, mate with) females.
- If our hypothesis is correct, fewer male beetles should be captured in sentinel traps (traps containing females) surrounded by mass disruption lures than in sentinel traps surrounded by control lures: i.e. we should catch more beetles in sentinel traps from control than from treated plots.

Materials and Methods

Study Sites, Traps and Lures

Study sites were commercial hop yards in the Treasure Valley of southwest Idaho, and the Yakima Valley of south central Washington.

Sentinel traps were pitfall traps fitted with aluminum or plastic funnels and buried between rows of hop plants with funnel rims flush with the soil surface.

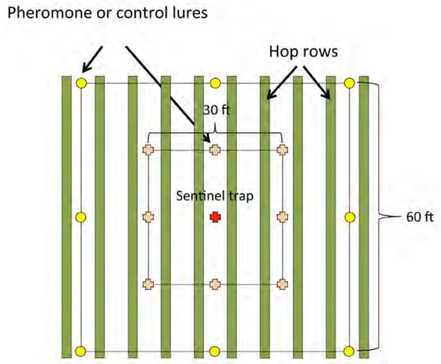
In preliminary experiments caged female *P. californicus* did not reliably emit pheromone, so could not be used to assess mating disruption effects on males. We therefore used lures containing a relatively low pheromone dose (0.1 mg) as surrogate females in sentinel traps. These lures are likely to be more attractive than an actual female (Rodstein et al 2011), but we reasoned this would give a conservative estimate of mating disruption potential.

Therefore, in small and large plot experiments, sentinel traps were baited with lures consisting of low-density press-seal polyethylene bags (below left) loaded with 0.1 mg of pheromone in 100 µl HPLC grade hexane and suspended over the trap funnels (below right).

Materials and Methods

Small plot experiments (2009)

For the small plot mating disruption experiment, we surrounded sentinel traps with lures containing 1.0 mg of synthetic pheromone (mating disrupted plots) or with lures containing only solvent (control plots). Lures surrounding sentinel traps contained ten times the dose of lures in the sentinel traps. Pheromone and control lures, were suspended ~2 ft. above the ground on wire flags (right) . The experiment was conducted on evenings of 14 to 17 July 2009. We set up eight pheromone or control lures in a square configuration, 30 or 60 ft. on a side, with the sentinel trap in the center, to test for any effects of trap spacing on the number of males captured in the sentinel trap (see diagram below). These trap spacings were based on the 15 ft spacing of rows in hop yards.



The four treatment combinations (mating disruption vs. control at each trap spacing) were assigned randomly to four commercial hop yards, 20-40 acres in area, that were naturally infested with *P. californicus* and separated from one another by at least ¼ mile. The experiment was repeated on four consecutive evenings from 10 to 13 July 2009 with treatments rotated across fields each day. We recorded the number of male beetles in traps each morning and then released them into vegetation outside the squares of traps and at least 60 ft. from the nearest trap, with about equal numbers released at each cardinal compass direction.

Data were analyzed by analysis of variance (ANOVA) as an imperfect Latin Square blocked by field and day. We used orthogonal contrasts to test differences between in the mean number of male *P. californicus* that were captured by sentinel traps in mating disrupted vs. control plots at each lure spacing.

Large plot experiments (2010)

As a result of the success of the small plot experiment (see results), a large plot experiment using commercial pheromone dispensers was conducted from 23 July to 20 August 2010 in commercial hop yards in Canyon Co, ID. There were two replicates of four treatments each for a total of 8 plots. Plots were approximately one acre of hops defined as a 6-pole by 8-pole array: 48 poles per plot. There were three mating disruption treatments consisting of different numbers of commercial emitters (Isomate dispensers, Pacific Biocontrol Corp., Vancouver, WA, each loaded with 50 mg of *P. californicus* pheromone) per pole in each plot, plus a non-disrupted control plot:

Treatment 1: 1 emitters per pole (= 50 mg pheromone per pole)
Treatment 2: 2 emitters per pole (=100 mg pheromone per pole)
Treatment 3: 3 emitter per pole (= 150 mg pheromone per pole)
Treatment 4: 1 blank emitter per pole (=0 mg pheromone per pole: control)

Materials and Methods

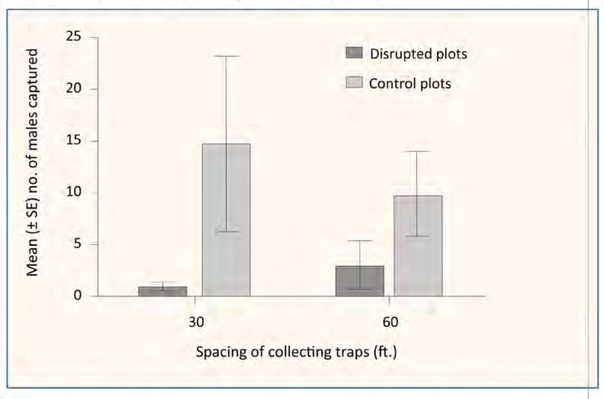
We recorded the number of male beetles in each of ten sentinel traps placed in plot centers each morning and then released the beetles into vegetation at least 60 ft. from the nearest trap, with about equal numbers released at each cardinal compass direction.

Data were analyzed by split plot ANOVA to account for correlations between sampling the same plots on consecutive days and means separated using Student's protected t test ($p \leq 0.05$).

Results

Small plot experiments (2009)

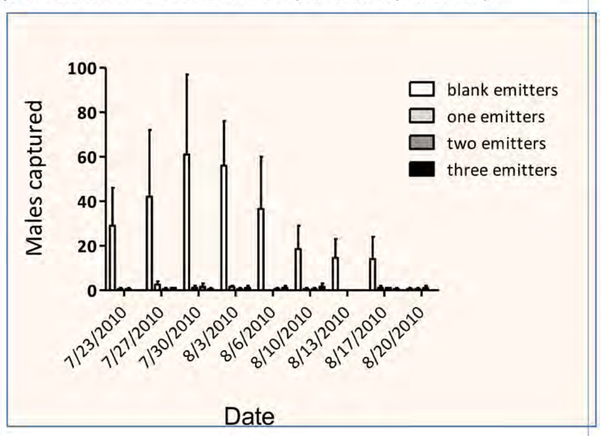
- Sentinel traps in mating disrupted plots captured a mean of 2.0 ± 1.2 males whereas those control plots captured 12.4 ± 4.5 males, an 84% reduction (below, means significantly different; ANOVA $F_{1,6} = 44.1$, $P = 0.0006$).



- The spacing of lures did not significantly influence the number of males captured by sentinel traps (7.8 ± 4.70 and 6. 4 ± 2.54 in traps spaced at 30 and 60 ft., respectively; ANOVA $F_{1,6} = 0.093$, $P = 0.77$).

Large plot experiments (2010)

The number of males captured by sentinel traps increased from 23 to 30 July then decreased to 20 August, when the test was halted (below). This decrease represents the natural decline in the beetle population in August and was not due to decreasing pheromone concentration since sentinel trap lures were replaced weekly.



- Sentinel traps captured significantly ($F_{(3, 32)}$=28.52, p= 0.0105) more male beetles in control plots than in mating disrupted plots.
- There was no difference in the capture of males in plots containing 1, 2, or 3 pheromone emitters (50, 100 0r 150 mg of pheromone) per pole.
- The no. of beetles captured in sentinel traps in control plots(544) was about 93% of the total number beetles captured by sentinel traps in mating disrupted and control plots (582).

Conclusions

- Capture of males in sentinel traps in mating disrupted plots was reduced by 84% and 93%, compared to control plots, in small and large plot mating disruption experiments, respectively.
- In large plot experiments, there was no difference in the percentage reduction in the number of males captured by sentinel traps surrounded by 1, 2, or 3, 50 mg emitters per pole.
- These results supported the hypothesis that the number of males captured by sentinel traps can be reduced by surrounding the sentinel traps with pheromone-baited lures and indicates that mating disruption using commercial pheromone emitters is a potentially viable strategy for managing *P. californicus* in hop.

Current Research

Research in 2011 is evaluating the efficacy of Isomate pheromone emitters (Pacific Biocontrol Corp., Vancouver, WA), in 2.5 acre plots each with a different number of pheromone dispensers per acre:

Control: no dispensers

25/acre: one dispenser on every other pole in each pole row

50/acre: one dispenser per pole on each pole row.

100/acre: one dispenser per pole in each pole row, plus one dispenser on string, between poles on non-pole rows.

Three replicates of the experiment have been established in grower fields in Idaho and three in Washington, for a total of six replicates (an example replicate is shown below). Control and lower dispenser treatments are situated upwind of higher dispenser treatments (NNW, according to historical data from the Western Regional Climate Center).

As in the previous studies, the experiment will be evaluated by comparing the number of male beetles captured in sentinel traps (four per plot) placed in the center of each plot: plots having lower numbers of dispensers per acre should have higher trap catches than plots with higher numbers of dispensers per acre.

Data will be analyzed and presented at the Annual meeting of the Hop Research Council in January of 2011.

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Acknowledgments

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