Development of an Attract and Kill Device for Orchard Pests

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Concerns about worker and food safety, environmental contamination and insecticide resistance are encouraging the development of new methods of delivering insecticides to pests. This is especially true for high value specialty crops — including tree fruit — where pest complexes require multiple insecticide applications. Researchers at Michigan State University are developing an exciting new attract and kill approach for orchard insect pests. The goal of our work is to develop a mating disruption like platform that will provide increased control with lower material and labor costs.

Use of behavior-modifying chemicals — semiochemicals — has revolutionized the management of many major tree fruit pests. Mating disruption (MD) is the most common semiochemical based management strategy with over 400,000 acres worldwide using mating disruption to control codling moth (Cydia pomonella [L.]) alone (Gut et al., 2004; Witzgall et al., 2008). Adoption of MD has been impeded by the high application costs of hand-applied dispensers and inconsistent control from alternative formulations (Witzgall et al., 2008).

Ongoing research at MSU has shown that pheromone based management systems that remove male moths from the population are much more effective than systems that only distract males for a limited time period (Miller et al. 2010). Removal of males responding to a lure is typically achieved either through mass trapping or where semiochemicals are combined with insecticides in an attract and kill device. Most current attract and kill formulations consist of droplets of paste or gel containing a mixture of semiochemicals and insecticides. A major problem with these formulations is that target pests have to contact a very small surface (< 0.5”) to pick up insecticide and in some cases close proximity and/or contact with the substrate is repellent due to over-sensitization. Recently, we found that separation of a substrate from the pheromone source dramatically increases contact time by codling moth (Huang et al. 2013). Male codling moth spent nearly four times longer in the vicinity of the lure when a substrate was placed in front of the lure, compared to a naked lure or substrate placed underneath the lure. We hypothesize that this difference was largely due to the moth’s inability to locate the naked lure, preventing overstimulation and repellence.

Our new attract and kill device solves this problem by providing the target insects with a relatively large surface area (ca. 40 inches²) to interact with that also serves as a barrier between the actual release device and direct physical contact (Figure 1). Our device consists of a 4” x 5” fabric pouch comprised of deltamethrin impregnated nylon fabric containing a semiochemical lure. The idea is modeled on insecticide treated mosquito nets used in the tropics to mitigate mosquito-transmitted diseases. The most obvious limitation of our device is that a good attractant is needed to bring pests into contact with the killing surface.

Target Pests

The Oriental fruit moth Grapholita molesta (Busck), is a key pest of peach, pear, and apple worldwide, capable of reducing crops by up to 50%. The Japanese beetle (Popillia japonica Newman) is a serious pest of many specialty crops either through direct damage to fruit or indirect damage by skeletonizing leaves. Management of both of these pests in tree fruit has traditionally relied on multiple applications of broad-spectrum insecticides. However the organophosphate...
phase-out mandated by the Food Quality Protection Act has reduced the number of tools available to manage these important pests.

Sex-pheromone-based mating disruption of Oriental fruit moth has been a good alternative to broad-spectrum neurotoxins and products for Oriental fruit moth disruption are commercially available. However, disruption requires large amounts of pheromone per dispenser (75-250 mg), releasing from 600-1000-fold more than the amount by a calling female per hour with hundreds of dispensers applied per acre. Sprayable formulations of pheromone provide an alternative method, but require more frequent applications. Our devices appear to provide reasonable disruption at 50 devices per acre and with a more than 1000-fold reduction in the amount of pheromone compared to mating disruption dispensers.

Japanese beetles have traditionally been monitored in traps baited with plant semiochemicals and an aggregation pheromone. Both male and female beetles respond to lures making them an especially attractive target for attract and kill tactics. Previous attempts at attract and kill for Japanese beetle have been limited utility because they have relied on relatively expensive insect traps (ca. $10-20 per trap) that have to be serviced on a regular basis to remain effective. Thus, previous studies utilizing a mass trapping approach for Japanese beetle management have typically consisted of five to ten traps per acre and have had little success (Hamilton et al. 1971; Gordon and Potter 1985, 1986; Switzer et al. 2009). In fact, many pest management practitioners have observed that damage around Japanese beetle traps is typically higher than in areas lacking traps! In our preliminary studies on Japanese beetles we have established attract and kill densities of 50 devices per acre — ten times the number of traps used in most mass trapping studies.

**Current Research**

We have conducted a series of promising laboratory and field studies evaluating the potential of our attract and kill device for the Oriental fruit moth. The first of these have focused on determining the optimal dosage of deltamethrin to maximize killing efficiency, potential of Oriental fruit moth to contact our device and the longevity of deltamethrin on our device. Ongoing experiments have used video recordings of wild insect approach and contacts with our device to determine the amount of time spent in contact with our device as well as an evaluation of the impact of our device on trap captures in treated and untreated small plot experiments. Our most recent work has expanded the evaluation of our device for management of Japanese beetle.

**Optimal Rate of Deltamethrin.** We evaluated four rates of deltamethrin, ranging from 0.02 (1X), 0.06 (3X), 0.2 (10X), and 0.6 mg/cm² (30X) deltamethrin solutions. Control pouches were treated only with acetone. Ten Oriental fruit moth males (2-3 days old) were placed as a group of two, confined by a petri dish, onto a treated pouch for 5, 10, 15, 30 and 60s. After exposure, males were kept in clean diet cups. Moth mortality and “knock down” were assessed after 2, 4 and 24 h exposure. Overall, as the dosage of deltamethrin in fabric increased, numbers of moth knockdown or dead increased 2, 4, 24 h after exposure. We determined that the 10X pouches were a likely optimum dosage for further studies as 5 second exposure results were comparable with the 30X pouches (Figure 2).

**Voluntary Contact Experiment.** The next step of our study was to evaluate whether moths would be repelled by our chosen dosage of deltamethrin. This experiment was run in a wind tunnel where individual male moths were flown to a 0.1 mg Oriental fruit moth commercial lure contained within a pouch that was either treated at the 10X rate or untreated. Following each trial, individual Oriental fruit moth that contacted pouches were placed in a plastic cup to observe knockdown or death after 1 and 24 h exposure. As expected, Oriental fruit moth males exhibited similar responses when exposed to either control pockets or 10X pouches, indicating no repellency from deltamethrin. Some moths stayed on pouches for over 1 min, but the majority of moths stayed for less than 50 seconds. Among those moths that contacted treated pouches, nearly 100% were either knocked down or killed after voluntary exposure (Figure 3).

**Device Longevity.** We evaluated the longevity of our device in a field aging experiment where pouches were aged outdoors and evaluated through laboratory forced contact bioassays of Oriental fruit moths. We evaluated three types of pouches: an untreated control pouch, our 10X formulation, and 10X with a UV absorber compound: 2, 4-dihydro xybenzophenone (10X+B). Lab bioassays were conducted at 7 d intervals to day 35, 14 d interval to day 105, and 30 d interval to day 135. Our devices maintained killing efficacy for the entire study period with no detectable drop in efficacy. Surprisingly, the addition of a UV blocker actually decreased efficacy of deltamethrin at the beginning of aging study (before day 21) but did not appear to improve efficacy at the end of the study (Figure 4). These results are very encouraging and suggest that a single device will easily provide a full season of lethal activity. The remaining challenge will be the development of a release device that can provide an equivalent period of attractiveness for a similar time period.
Initial Field Evaluation of Attract and Kill for Oriental Fruit Moth

We evaluated our attract and kill device in ½ acre apple plots by comparing trap captures in plots containing: 50 of our 10X pouches baited with 0.1 mg lure; 50 of our untreated pouches baited with a 0.1 mg lure; 50 Isomate® Rosso mating disruption dispensers or an untreated control. The inclusion of untreated pouches allowed us to evaluate any potential mating disruption due to our devices as opposed to attract and kill. Our treated pouches provided superior trap shut-down compared to all the other treatments (Figure 5). This is exciting because it indicates that the inclusion of the killing agent is critical to the function of our device and that trap shut down comparable or superior to that provided by mating disruption can be achieved with a 1000 fold reduction of pheromone—the most expensive component of mating disruption formulations.

Japanese Beetle

Japanese beetle is the next pest that we are targeting with our attract and kill device. Research on Japanese beetle was underway at the time this article was developed so only preliminary results are available. Our first experiments have focused on video evaluation of contact time of wild beetles to either our 10X pouches or a control pouch lacking deltamethrin, laboratory assays determining the contact time needed to deliver a lethal dose and a field experiment evaluating the impact of 50 attract and kill devices on trap capture in ½ acre apple plots.

Field studies have utilized the Trece Japanese Beetle Dual Lure that combines plant semiochemicals with the Japanese beetle aggregation pheromone. Initial findings have been very promising with beetles readily contacting our devices in the field (Figure 6) and 5 seconds of forced contact resulting in nearly 100% mortality. In our field evaluation we have seen an over five fold reduction of beetles trapped in a central trap in plots containing the 10X devices compared to a control plot while plots with 0X devices (lacking deltamethrin) had a minor reduction in trap capture (Figure 7). This suggests that our attract and kill devices are eliminating 5/6ths of the beetles responding within the treated area. Further questions for evaluating the potential of our device for Japanese beetle include: what is an effective treatment area to manage local populations and how will removal of adults impact following generations?

Implications and Next Steps

Our attract and kill device has a high potential to provide a new semiochemical based approach for pest management that builds upon the successes seen in mating disruption. One of the most exciting aspects of this approach towards pesticide delivery is that it does not contribute to residues on fruit and is likely to have limited impacts on beneficial insect populations. While it is possible that our device may not provide stand-alone pest management—as is the case with...
mating disruption— the need for reduced amounts of pheromone and potentially fewer dispensers per acre should significantly reduce the end cost to the grower. Furthermore, it may be feasible to combine semiochemicals in a single device that targets multiple species!

Multispecies management is one of the next questions we will address in our research program. For this to function the semiochemicals must be non-repellant across species and we are actively pursuing this question in laboratory studies. We are also planning to evaluate attractants for invasive pests such as the brown marmorated stink bug (Halyomorpha halys Stål) and spotted wing drosophila (Drosophila suzukii [Matsumura]). However, successful application for these pests will depend on the availability of highly attractive lures.

A final area of interest for our future research is the identification of additional compounds that can serve as killing agents in our device. While this is an especially important consideration for organic producers who face regulatory limitations on the types of pesticides that can used on their operations, it may also prove important for resistance management.

Literature Cited

Matthew Grieshop is an Associate Professor of Entomology at Michigan State University that specializes in organic pest management, Juan Huang is a graduate student who works with Larry Gut and Larry Gut is a professor of Entomology at Michigan State University who leads MSU’s program of tree fruit insect management.