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# Evaluating plant volatiles for monitoring natural enemies in apple, pear and walnut orchards

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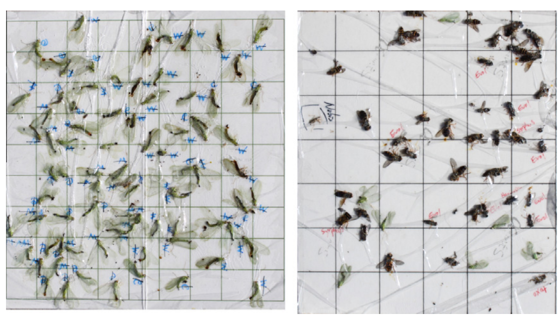
## HIGHLIGHTS

- A broad range of natural enemies can be readily trapped using plant volatiles.
- All hymenopteran taxa tested responded strongly to PAA.
- Syrphid flies responded strongly to 2-phenylethanol.
- *Chrysoperla* spp. responded best to multi-component lures.

## GRAPHICAL ABSTRACT



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## ABSTRACT

The ability to estimate natural enemy abundance is crucial to the integration of biological control into IPM programs. Traditional sampling approaches for natural enemies are few and most are inefficient, but recent studies suggest attraction of natural enemies to plant volatiles may be a useful proxy for direct sampling. We evaluated various combinations of herbivore-induced plant volatiles and floral volatiles as monitoring tools for natural enemies found in apple, pear, and walnut orchards in California, Oregon, and Washington. In 2010 we used a full factorial experimental designs to evaluate lures for all combinations of acetic acid (AA), acetophenone (AP), phenylacetaldehyde (PAA) and 2-phenylethanol (PE). Of nine natural enemy taxa analyzed, we found syrphid flies responded strongly to PE, but combining AA with PE attenuated trap catch and combining PAA to PE eliminated the activity of PE. *Chrysoperla* spp. (Chrysopidae) responded strongly to most of the individual compounds and the various interactions between the components allowed multiple ways to achieve roughly the same trap catch. All of the hymenopteran taxa collected responded strongly to PAA, and PAA containing lures were nearly always a component of the top eight lures. A smaller factorial experiment testing all possible combinations of AA, PAA and methyl salicylate (MS) showed that single component AA or MS lures were generally not significantly different than the controls for all taxa tested, but for the hymenopteran taxa, traps baited with MS+PAA performed the best or were not significantly different than the best performing lure. A 2011 trial was conducted to test the influence of the addition of AA and/or MS on previously tested lures. Combining AA or MS with other lures, improved the capture of *Chrysoperla* spp.; *Scaeva pyrastri* (L.) (Syrphidae) capture was enhanced when MS was used with PE; and PE was attractive to the three syrphid

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flies, *Chrysoperla* spp., and the parasitoid *Aphelinus mali* (Haldeman) (Aphelinidae). The differential responses to various blends exhibited among taxa show that combinations of plant volatiles can be chosen to increase specificity of attraction to a few taxa or increase the number of species attracted. This flexibility should add to the general value and breadth of use of plant volatile monitoring lures.



## 1. Introduction

Integrated Pest Management (IPM) depends on a biological control (BC) component to ensure the long-term stability of arthropod management programs (Stern et al., 1959a,b; van den Bosch and Stern, 1962). In most agro-ecosystems, the main BC tactic used is conservation of beneficial natural enemies, where ideally, the timing, intensity, spatial location, and method of pest suppression is carefully designed to have a maximum effect on pest(s) and minimal effects on important natural enemies. Maintaining conservation BC in an IPM program requires a deep understanding of the phenology of the pests and natural enemies involved and effective ways to estimate their abundance. Only from this information can we determine if BC can suppress a given pest species or if other interventions may be required to prevent economic damage.

Numerous sampling protocols for pest species have been developed for orchard crops (Beers et al., 1994). Many of these sampling protocols are time saving sequential or binomial sampling plans that are efficient and allow IPM specialists to quickly gauge how the pest populations vary over time (Beers and Jones, 2004; Binns and Bostanian, 1990; Binns and Nyrop, 1992; Jones, 1990, 1994; Nyrop et al., 1989, 1999). Attractant traps have also proven exceptionally useful for estimating pest phenology and abundance (Croft and Hoyt, 1983; Riedl, 1980), with huge changes in efficiency occurring since the techniques have improved for the identification and formulation of pheromone lures (particularly for lepidopteran pests). Lure-based attractant trapping has allowed the rapid development of phenology models for pests (Jones et al., 2010; Welch et al., 1978) and the magnitude of trap catch has been used as way to estimate action thresholds for several pests, notably codling moth, *Cydia pomonella* (L.) (Croft and Hoyt, 1983).

IPM practitioners have a much poorer picture of how natural enemy population levels are varying over time and of the diversity of natural enemies present in a system that are suppressing pest populations. Until recently, there has been little effort to develop trapping protocols to sample beneficial natural enemies and estimate their phenology. However, studies over the last 10 years that have attempted to manipulate natural enemy populations using several herbivore-induced plant volatiles (HIPVs) or floral volatiles (from here on simply called plant volatiles) (James, 2003b, 2006; James and Price, 2004; Khan et al., 2008; Simpson et al., 2011) have indirectly show that plant volatiles combined with traps can be used as monitoring tools. HIPV's are generated by a plant in response to herbivore feeding, and multiple natural enemies are thought to use these volatiles to improve host/prey location (de Boer et al., 2008; Dicke et al., 2003, 1990; Dicke and Grostal, 2001; Fatouros et al., 2005; Vet and Dicke, 1992). While the value of using plant volatiles to manipulate natural enemies is still unclear (James, 2003b, 2005b; Jones et al., 2011; Kaplan, 2012; Khan et al., 2008), their use as monitoring tools could potentially lead to better pest management by improving our understanding of natural enemy population abundance, diversity, and phenology (Jones et al., 2009).

Before plant volatiles can be used as reliable monitoring tools, their sensitivity and specificity must be assessed in a variety of situations. The nature of their specificity is particularly important to understand because these kairomones are not species-specific sex pheromones and may be attractive to a wide variety of arthropods. Thus some volatile combinations may catch a diversity of natural enemies that have only minor or no suppressive effects on the pests of interest. Our studies were designed to evaluate several plant volatiles both alone and in various combinations. Our goal was to discover if we could optimize blends for potential indicator species that could be used to evaluate BC services of secondary pests (such as aphids, mites, or scales) in orchards and minimize their undesirable attraction to honeybees. We also evaluated volatile blends for attraction of taxa that occurred in high numbers that may be of interest for ecological or systematics applications beyond the specific orchard systems investigated. Studies were conducted in apple, pear and walnut orchards in the western US.

## 2. Materials and methods

### 2.1. Lure construction

Lures were made using 5 cm wide × 7.5 cm long sections of polyethylene tubing (Associated Bag Company, Milwaukee, WI, USA). Tubing was heat sealed at one end to form a bag and a 3.8 cm long piece of dental wick was placed into the bag; the chemical to be tested was applied to the wick and then the open end of the bag was heat-sealed. Only a single chemical was added to the dental wick and we refer to this as a lure. When multiple volatiles were to be tested, multiple lures were placed within a single trap and this is referred to as a multi-component lure. Tubing thickness for lure construction varied by compound; information for each type of lure is given in Table 1. All lures were formulated to last at least 40 days at the specified release rate based on unpublished field release rate studies (Jones and Baker, unpublished) and preliminary trapping studies using the methods described by Jones et al. (2011).

**Table 1**
Volatile components used for lures evaluated for natural enemy trap catch in western orchards 2010–2011.

| Attractant | Bag thickness (mm) | Release rate (mg/d)[1] | Volume (ml) | Attractant source |
|---|---|---|---|---|
| Acetic Acid (AA) | 0.1016 | 50.2 | 3.0 | Acros Organics-222140010 |
| Acetophenone (AP) | 0.1016 | 58.7 | 3.0 | Acros Oganics-102410010 |
| Geraniol (GER) | 0.0381 | 9.9 | 1.0 | SAFC Supply Solutions-W250708-1 KG-K |
| Methyl Salicylate (MS) | 0.1524 | 78.6 | 3.5 | SAFC Supply Solutions-W274518-1 KG-K |
| Phenylacetaldehyde (PAA) | 0.1524 | 4.9 | 0.5 | SAFC Supply Solutions-W287407-1 KG-K |
| 2-phenylethanol (PE) | 0.0381 | 12.8 | 1.0 | Sigma–Aldrich 77861–250 ml |