



Insect aggregation pheromones: An invitation for vegetable IPM development

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Chrysomelid leaf beetles and pentatomid and coreid bugs often use male-produced aggregation pheromones (attractive to males and females) to colonize hosts, including crops. Some important pests' aggregation pheromones are already known and synthesized.

Availability of synthetic pheromones offers opportunities to develop behavioral control as an important tactic in vegetable IPM, while reducing pesticide applications and negative non-target effects in pest management.

Additionally, plant-produced attractants, often less expensive, in some cases add to or even synergize pheromone-based attraction.

Important pest species include Colorado potato beetle, cucumber beetles, crucifer flea beetles, harlequin bug, brown marmorated stink bug, and leaf-footed bugs (*Leptoglossus* spp.).

Tactics that are promising include monitoring, "supercharged" trap cropping, mass-trapping, attract-and-kill baiting, and push-pull systems.

However, challenges remain with cost-efficient synthesis, development of time-release formulations, and management of vicinity effects arising from aggregations. And, registration of uses other than trapping is surprisingly cumbersome with US EPA, given the potential benefits in pesticide reduction.

How can we develop, commercialize, and implement these tools for vegetable IPM?

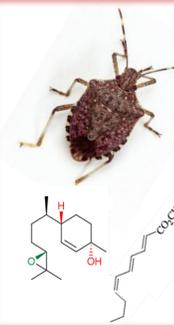
STAGES from DISCOVERY to IPM IMPACT

Discovery of a pheromone or other semiochemical is necessary but not sufficient to its practical use.

Several stages are required for impact in pest management:

1. behavioral discovery: insect unequivocally responds to chemical stimuli within the same species
2. chemical discovery: a discrete chemical or group of chemicals elicits insects' behavioral response
3. chemical identification: structure of the pheromone characterized (including stereochemistry)
4. chemical synthesis: the pheromone is synthesized and confirmed as identical with the natural chemical(s)
5. pheromone for lab bioassay: sufficient amount of pheromone is synthesized for small groups of insects
6. pilot bioassays: sufficient synthesized pheromone tested in small-scale lab or field bioassays
7. pheromone for field deployment: sufficient amount of pheromone available for deployment in the field
8. field effects on insect populations: and pest damage, with minimal non-target effects on beneficials
9. pilot-scale pheromone synthesis: availability of pilot-scale synthesis at a reasonable cost
10. development of appropriate time-release formulation for pheromone and other components
11. **Impact:** multi-year, multi-location efficacy on full field scale, leading to commercialization

stages



Brown marmorated stink bug

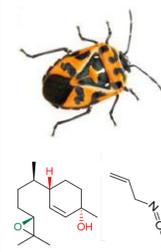
Halyomorpha halys
(Hemiptera: Pentatomidae)

stage 11

Hi!

Pheromone ("murgantiol" commercially available as 8-isomer mix) attraction is synergized by the pheromone (MDT = methyl decatrienoate) of a sympatric stink bug species (*Plautia stali*) from Asia. This eavesdropping could be a proxy for food signals. Plant volatiles have at most minor influence in attraction for this generalist feeder. "Trap trees" successful in orchard systems.

BMSB: Khirmian 2014b J.Nat.Prod.; Weber et al. 2014a, J.Econ.Entomol.; Leskey et al. 2015a, J.Chem.Ecol.; Leskey et al. 2015b, Environ.Entomol.; Weber et al. 2017, J.PestSci.; Morrison et al. 2017, Agric.For.Entomol.; Weber et al. 2020a, J.Econ.Entomol.

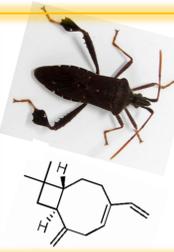


Harlequin bug

Murgantia histrionica
(Hemiptera: Pentatomidae)

stage 8

The commercialized pheromone "murgantiol" is an isomeric mix identical to that for BMSB. Isothiocyanate plant volatiles are additive to pheromone attraction, are however toxic and may be repellent at higher release rates, necessitating carefully controlled release for practical use. Could be useful for "supercharged" trap crops. Harlequin Bug: Zahn et al. 2008, J.Chem.Ecol.; Wallingford et al. 2013, J.Econ.Entomol.; Weber et al. 2014b, J.Chem.Ecol.; Khirmian et al. 2014b, J.Chem.Ecol.; Cabrera Walsh et al. 2016, J.PestSci.; Thrift et al. 2018, Environ.Entomol.; Wallingford et al. 2018, J.Econ.Entomol.; Bier et al. 2021, J.Econ.Entomol.

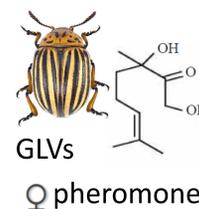


Leaf-footed bugs

Leptoglossus species
(Hemiptera: Coreidae)

stage 8

Newly-discovered pheromone "leptotriene" is attractive to at least three species of *Leptoglossus* (*L. zonatus*, *L. occidentalis*, *L. oppositus*), but not to some other pest species including *L. phyllopus*! Trapping under development. Millar et al. 2022, J. Nat. Products



Colorado potato beetle

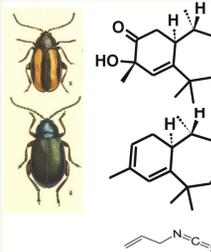
Leptinotarsa decemlineata
(Coleoptera: Chrysomelidae)

stage 6

GLVs
♀ pheromone

Male-produced pheromone, decemdiol, is highly attractive to both sexes. Green leaf volatiles may or may not be useful. Female-produced sex pheromone may also be useful but is not yet identified. Beetles are also deterred by aggregation pheromone of predatory stink bug (*Podisus*), offering opportunity for a potential push-pull system of behavioral control.

CPB: Jermy&Butt 1991, Ent.Expl.Appl.; Dickens et al. 2002, J.Exp.Biol.; Dickens 2006, J.Appl.Entomol.; Kuhar et al. 2006, Agric.For.Entomol.; Weber et al. 2020b, J.PestSci.; Haber & Weber 2021, Pest Mgt.Sci.



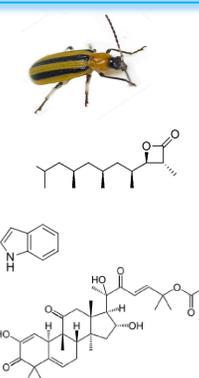
Crucifer flea beetles

Phyllotreta cruciferae and *Phyllotreta striolata*
(Coleoptera: Chrysomelidae)

stage 6

Pheromones for crucifer flea beetle and striped crucifer flea beetle are complex terpenes for which synthesis is difficult, but targeted for improvement. The two pheromones do not interfere with one another, and the host-specific plant volatile allyl isothiocyanate (mustard oil) is attractive to both species.

Bartelt et al. 2001, J.Chem.Ecol.; Bartelt et al. 2003, Synthesis; Soroka et al. 2005, J.Chem.Ecol.; Toth et al. 2005, J.Chem.Ecol.; Beran et al. 2011, J.Chem.Ecol.; Beran et al. 2016, J.Chem.Ecol.; Weber et al. 2022, J.Econ.Entomol.



Striped cucumber beetles

Acalymma vittatum and *A.trivittatum*
(Coleoptera: Chrysomelidae)

stage 7

Aggregation pheromone "vittatalactone" explains adults' rapid attack of cucurbit seedlings. Synthesis difficult but now achieved with impure mixture. Vittatalactone is highly attractive not only to striped cucumber beetle, but also to western striped cucumber beetle, spotted cucumber beetle, and squash bugs! Cucurbitacins (bitter melon chemicals) stimulate feeding of cucumber beetles and form basis for bait; floral volatile indole is cheap & attractive but (unlike other floral odors) doesn't attract pollinators.

Smyth&Hoffmann 2003, J.Ins.Behav.; Morris et al. 2005, J.Nat.Prod.; Weber 2018, J.Econ.Entomol.; Brzozowski et al. 2022, J.PestSci.; Weber et al. 2022, Environ.Entomol.; Haber et al. 2023, J.PestSci.; Pasteur et al. 2023, Environ.Entomol.; Weber et al. 2023, J.Chem.Ecol.; Wallingford et al. 2024, Horticulturae; Wallingford et al., J.Econ.Entomol., in review.