Semiochemicals and Entomopathogenic Microbials

Subjects: Entomology

Contributor: Anamika Sharma

Biological control agents and semiochemicals have become essential parts of the integrated pest management of insect pests over the last several years, as the incorporation of semiochemicals with natural enemies and entomopathogenic microbials has been gaining significance. Semiochemicals can enable the successful dispersal of entomopathogenic microbials. Using semiochemicals to disseminate microbial pathogens is still at the initial stage. For dispersal of entomopathogenic fungus semiochemicals have been successfully used in field conditions, however same can not be said about the other microbials such as specially for bacterial and viral entomopathogens.

entomopathogenic fungus | attract and kill | autodissemination | entomopathigenic nematodes

1. Fungi

Pathogens may be dispersed naturally by parasitoids, predators, and the feces of insects, birds, and mammals, and surface contamination [1]. However, for entomopathogenic fungi, natural dispersal, in additional to the aerial movement of spores, is also known to occur through the movement of the targeted insect pests and pollinators, as shown in honey bees in canola production, where honey bees disperse *B. bassiana*, increasing the mortality of *Lygus* sp. (Hahn) (Hemiptera: Miridae) [2][3]. A selective and assisted dissemination technique called auto-dissemination is also extremely helpful in spreading entomopathogens [1]. Auto-dissemination can be used to target both adults and larvae of some insect pests [4][5][6]. Semiochemicals are being used to increase the rates of fungal infection in several insects. Successful examples of the use of combinations of semiochemicals and entomopathogenic fungi include bark beetles (*I. typographus*), weevils (*Cylas formicarius* Fabricius [Coleoptera: Brentidae], *Cosmopolites sordidus* Germar [Coleoptera: Curculionidae]), moths (*Plutella xylostella* L. [Lepidoptera: Plutellidae]), stink bugs (*Plautia crossota* stali Scot [Hemiptera: Pentatomidae]), thrips (*Megalurothrips sjostedti* Trybom [Thysanoptera: Thripidae]), and aphids (*Phorodon humuli* Schrank [Hemiptera: Aphididae]) [7]. To make this method successful, an appropriate physical separation (including the distance) between semiochemicals and entomopathogenic fungus is needed to achieve the maximum output of autoinoculation [8].

Plants also host entomopathogenic fungi naturally [9], that remain as endophytic fungi after the conidia of an entomopathogenic fungus germinate and enter the plant cuticle [10]. The presence of these endophytic entomopathogenic fungi in plants causes mycosis in different insect pests [11]. Epiphytic fungi on plants are also reported to attract insects. Western yellowjacket [*Vespula pensylvanica* Saussure (Hymenoptera: Vespidae)] and the German yellowjacket [*V. germanica* Fabricius (Hymenoptera: Vespidae)] vector the fungus *Aureobasidium* *pullulans* ([de Bary] Arnaud) (Dothideales: Dothioraceae). A study done in orchards in Washington, USA found that the volatile compounds emitted by this fungus can attract eusocial wasps and that wasps and fungi appear to have a symbiotic relationship [[12]]. In a laboratory experiment also done in the USA, it was found that the hymenopteran parasitoids *Roptrocerus xylophagorum* (Ratzeburg) (Hymenoptera: Pteromalidae) and *Spathius pallidus* (Ashmead) (Hymenoptera: Braconidae) are attracted to bluestain fungi (genus *Ophiostoma* [Syd. and P. Syd.]), which are associated with bark beetles (Coleoptera: Scolytidae) feeding in pine trees. This study also found that such fungus-based attraction might not function for short-range host location [[13]].

The 'lure and kill' method has been highly effective for controlling some insect pests by using semiochemicals (especially pheromones) in conjunction with entomopathogenic fungi. Successful examples include the management of sap-sucking insects such as aphids (*P. humuli*), thrips (*M. sjostedti*), green bugs (*P. crossota*), and chewing and biting insect pests such as bark beetles (*I. typographus*), weevils (*C. formicarius and C. sordidus*), and moths (*P. xylostella*) [[7]]. Nevertheless, in most cases, such as sex-specific semiochemicals, which attract only one sex, the method is less effective. In addition, the 'lure and kill' method is still not well developed for soil-dwelling insects, although Agriculture and Agri-Food Canada (AAFC) (Agassiz, BC, Canada) has created prototype granules of *Metarhizium brunneum* (Petch) (Hypocreales: Clavicipitaceae) combined with pheromone compounds that have showed some promising results for attracting species of *Agriotes* cutworms (Coleoptera: Elaterideae) to bait sources [[14]]. The use of pheromones in granulated or in pellet form could work well for soil-dwelling insects [[5]].

2. Nematodes

The efficacy of entomopathogenic nematodes (EPNs) mainly depends on the strain, formulation, and method of application [[15]]. However, in recent studies, several HIPVs from the roots of host plants that attract EPNs were examined as formulation additives. These HIPVs are secreted at damaged sites when their production is triggered by compounds in the saliva of phytophagous insects during feeding. Plants also release defense-related volatiles that can attract EPNs [[16],[17], [18]]. Furthermore, volatiles secreted by such nematodes also attract EPNs; for instance, the application of infected cadavers with EPNs proved to be more effective than the direct spraying of infective juveniles. When an extract of the infected cadavers was applied along with the aqueous suspension of *Heterorhabditis bacteriophora* (Poinar) Hb strain (Rhabdita: Heterorhabditidae), it was also found to be more infective than direct spraying to *Galleria mellonella* (L.) (Lepidoptera: Pyralidae) [[19]]. In another study, macerated hosts infected with *Steinernema carpocapsae* (Weiser) All strain, *Steinernema feltiae* (Filipjev) SN strain (both Rhabdita: Steinernematidae) and *H. bacteriophora*, increased the dispersal of these EPNs in soil columns [[20]]. Ascarosides (a group of glycolipids which regulate mating and development) secreted by several EPN species result in a greater dispersal of various EPNs, in both natural and synthetic form [[16]]. Pheromone extracts from *S. feltiae* (SN strain) or *S. carpocapsae* (All strain), when tested on *Tenebrio molitor* (L.) (Coleoptera: Tenebrionidae) larvae, showed an improved dispersal and efficacy, which suggests that pheromone-mediated enhancement of EPN efficacy could be achieved by exposing EPNs to specific pheromones [[21]].

Viruses

Most known entomopathogenic viruses are baculoviruses (four genera: Alpha-, Beta-, Gamma-, and Deltabaculoviruses), Reoviridae, Parvoviridae, or Nudiviruses [[22]]. The use of semiochemicals for the dispersal of entomopathogenic viruses has not been studied extensively. However, a combination of apple-associated yeasts and codling moth granulovirus (CpGV) increased the mortality of the codling moth (*Cydia pomonella* (L.) (Lepidopetra: Tortricidae) under both laboratory and field conditions [[23]]. The pheromone is known to increase the efficiency of the Granuloviruses in the insect pests *C. pomonella* and *Adoxophyes orana* (Fischer von Röslerstamm) (Lepidopetra: Tortricidae) [[24]]. In 1992, the potential of sex pheromone baited traps was first evaluated [48] in the USA, to auto-disseminate the *Baculoviruses* [nucleopolyhedrovirus (NPV)] against *Heliothis virescens* (Fabricius) (Lepidoptera: Noctuidae) [[25],[26]].

3. Bacteria

Among entomopathogenic bacteria, the best known is *Bacillus thuringiensis.* It has been known since 1901 and is used to manage several major insect pests in agriculture, forestry, and medicine [[22]]. Although the use of autoinoculator devices is reported to aid in dispersal of *Paenibacillus* (=*Bacillus*) *popilliae* (Dutky) (Eubacteriales: Bacillace) to manage *Popillia japonica* Newman (Coleoptera: Scarabaediae) [18,87], the use of semiochemicals to improve the efficacy and dispersal of bacteria has not been explored.

4. Protozoa

The inclusion of semiochemicals in the dispersion of protozoans to manage insect pests is a scantly explored area and needs further exploration. Shapas et al. [[27]] evaluated generations of *Trogoderma glabrum* (Herbst) and indicated that they were reduced after the dispersal of protozoan pathogen spores, *Mattesia trogodermae* Canning. Pheromone-baited (synthetic sex pheromone, (*E*)-14-methyl-8-hexadecenal) spore-transfer sites were used to disperse the spores. In this study, it was also indicated that males became attracted to females and these males induced attempted copulation with the pheromone source, aiding in spore transfer to males [[27]].

The publication can be found here: https://www.mdpi.com/2075-4450/10/12/439/htm

References

1. Vega, F.E.; Dowd, P.F.; Lacey, L.A.; Pell, J.K.; Jackson, D.M.; Klein, M.G. Dissemination of Beneficial Microbial Agents by Insects. In Field Manual of Techniques in Invertebrate Pathology: Application and Evaluation of Pathogens for Control of Insects and Other Invertebrate Pests; Lacey, L.A., Kaya, H.K., Eds.; Kluwer Academic: Dordrecht, The Netherlands, 2007; pp. 127–146.

2. Gavloski, J. Integrated pest management in canola and other Brassica oilseed crops: How far have we come, and what is still needed. In Integrated Management of Insect Pests on Canola and Other Brassica Oilseed Crops; Reddy, G.V.P., Ed.; CABI: Wallingford, UK; Oxfordshire, UK, 2017; pp. 295–304.
3. Sharma, A.; Reddy, G.V.P. IPM and Pollinator Protection in Canola Production in the USA. In Springer Book Series: Progress in Biological Control; Gao, Y., Hokkanen, H., Menzler-Hokkanen, I., Eds.; Springer: Berlin/Heidelberg, Germany, 2019.
4. L.A Lacey; R Frutos; H.K Kaya; P Vail; Insect Pathogens as Biological Control Agents: Do They Have a Future?. *Biological Control* **2001**, *21*, 230-248, 10.1006/bcon.2001.0938.
5. Reddy, G.V.P.; Sharma, A.; Guerrero, A. Advances in the Sse of Semiochemicals in Integrated Pest management: Pheromones. In Biopesticides for Sustainable Agriculture; Birch, N., Glare, T., Eds.; Burleigh Dodds Science Publishing Limited: Cambridge, UK, 2019; in press.
6. Michael G. Klein; Lawrence A. Lacey; An Attractant Trap for Autodissemination of Entomopathogenic Fungi into Populations of the Japanese Beetle Popillia japonica (Coleoptera: Scarabaeidae). *Biocontrol Science and Technology* **1999**, *9*, 151-158, 10.1080/09583159929730.
7. Francisco González; Cezary Tkaczuk; Mihaela Monica Dinu; Żaneta Fiedler; Stefan Vidal; Einat Zchori-Fein; Gerben J. Messelink; New opportunities for the integration of microorganisms into biological pest control systems in greenhouse crops. *Journal of Pest Science* **2016**, *89*, 295-311, 10.1007/s10340-016-0751-x.
8. Mfuti, D.K.; Subramanian, S.; van Tol, R.W.; Wiegers, G.L.; de Kogel, W.J.; Niassy, S.; du Plessis, H.; Ekesi, S.; Maniania, N.K. Spatial separation of semiochemical Lurem-TR and entomopathogenic fungi to enhance their compatibility and infectivity in an autoinoculation system for thrips management. Pest Manag. Sci. 2016, 72, 131–139
9. Fernando E. Vega; Francisco Posada; M. Catherine Aime; Monica Pava-Ripoll; Francisco Infante; Stephen A. Rehner; Entomopathogenic fungal endophytes. *Biological Control* **2008**, *46*, 72-82, 10.1016/j.biocontrol.2008.01.008.
10. Bruce L. Wagner; Leslie C. Lewis; Colonization of Corn, Zea mays, by the Entomopathogenic Fungus Beauveria bassiana†. *Applied and Environmental Microbiology* **2000**, *66*, 3468-3473, 10.1128/aem.66.8.3468-3473.2000.
11. E. Quesada-Moraga; F. J. Muñoz-Ledesma; C. Santiago-Álvarez; Systemic protection of Papaver somniferum L. against Iraella luteipes (Hymenoptera: Cynipidae) by an endophytic strain of Beauveria bassiana (Ascomycota: Hypocreales).. *Environmental Entomology* **2009**, *38*, 723-730, 10.1603/022.038.0324.
12. Thomas Seth Davis; Kyria Boundy-Mills; Peter J. Landolt; Volatile Emissions from an Epiphytic Fungus are Semiochemicals for Eusocial Wasps. *Microbial Ecology* **2012**, *64*, 1056-1063, 10.100

7/s00248-012-0074-2.

13. Brian T. Sullivan; C. Wayne Berisford; Semiochemicals from fungal associates of bark beetles may mediate host location behavior of parasitoids.. *Journal of Chemical Ecology* **2004**, *30*, 703-717, 10.1023/b:joec.0000028426.37482.17.
14. J. Todd Kabaluk; J. P. Lafontaine; John H. Borden; An attract and kill tactic for click beetles based on Metarhizium brunneum and a new formulation of sex pheromone. *Journal of Pest Science* **2015**, *88*, 707-716, 10.1007/s10340-015-0661-3.
15. Shapiro-Ilan, D.; Dolinski, C. Entomopathogenic Nematode Application Technology. In Nematode Pathogenesis of Insects and Other Pests; Campos-Herrera, R., Ed.; Springer: Cham, Switzerland, 2015; pp. 231–25
16. Sergio Rasmann; Tobias G. Köllner; Jörg Degenhardt; Ivan Hiltpold; Stefan Toepfer; Ulrich Kuhlmann; Jonathan Gershenzon; Ted C. J. Turlings; Recruitment of entomopathogenic nematodes by insect-damaged maize roots. *Nature* **2005**, *434*, 732-737, 10.1038/nature03451.
17. Ted C. J. Turlings; Ivan Hiltpold; Sergio Rasmann; The importance of root-produced volatiles as foraging cues for entomopathogenic nematodes. *Plant and Soil* **2012**, *358*, 51-60, 10.1007/s11104-012-1295-3.
18. Willett, D.S.; Martini, X.; Stelinski, L.L. Chemoecology and Behavior of Parasitic Nematode—Host Interactions: Implications for Management. In Chemical Ecology of Insects; Tabata, J., Ed.; CRC Press: Boca Raton, FL, USA, 2018; pp. 91–113
19. David I. Shapiro; Edwin E. Lewis; Comparison of Entomopathogenic Nematode Infectivity from Infected Hosts Versus Aqueous Suspension. *Environmental Entomology* **1999**, *28*, 907-911, 10.1093/ee/28.5.907.
20. Shaohui Wu; Fatma Kaplan; Edwin Lewis; Hans T. Alborn; David I. Shapiro-Ilan; Infected host macerate enhances entomopathogenic nematode movement towards hosts and infectivity in a soil profile. *Journal of Invertebrate Pathology* **2018**, *159*, 141-144, 10.1016/j.jip.2018.10.007.
21. Camila Oliveira-Hofman; Fatma Kaplan; Glen Stevens; Edwin Lewis; Shaohui Wu; Hans T. Alborn; Abigail Perret-Gentil; David I. Shapiro-Ilan; Pheromone extracts act as boosters for entomopathogenic nematodes efficacy.. *Journal of Invertebrate Pathology* **2019**, *164*, 38-42, 10.1016/j.jip.2019.04.008.
22. L.A. Lacey; D. Grzywacz; D.I. Shapiro-Ilan; R. Frutos; M. Brownbridge; M.S. Goettel; Insect pathogens as biological control agents: Back to the future. *Journal of Invertebrate Pathology* **2015**, *132*, 1-41, 10.1016/j.jip.2015.07.009.
23. Alan L. Knight; Peter Witzgall; Combining Mutualistic Yeast and Pathogenic Virus — A Novel Method for Codling Moth Control. *Journal of Chemical Ecology* **2013**, *39*, 1019-1026, 10.1007/s10886-013-0322-z.

24. Cross, J.V.; Winstanley, D.; Naish, N.; Helton, S.; Keane, G.; van Wezel, R.; Gakek, D. Semiochemical driven auto-dissemination of Cydia pomonella and Adoxophyes orana baculoviruses. IOBC Bull. 2005, 28, 319–32

25. Vega, F.E.; Dowd, P.F.; Lacey, L.A.; Pell, J.K.; Jackson, D.M.; Klein, M.G. Dissemination of Beneficial Microbial Agents by Insects. In Field Manual of Techniques in Invertebrate Pathology: Application and Evaluation of Pathogens for Control of Insects and Other Invertebrate Pests; Lacey, L.A., Kaya, H.K., Eds.; Kluwer Academic: Dordrecht, The Netherlands, 2007; pp. 127–146

26. M. D. Jackson; G. C. Brown; G. L. Nordin; D. W. Johnson; Autodissemination of a Baculovirus for Management of Tobacco Budworms (Lepidoptera: Noctuidae) on Tobacco. *Journal of Economic Entomology* **1992**, *85*, 710-719, 10.1093/jee/85.3.710.

27. T. J. Shapas; W. E. Burkholder; G. Mallory Boush; Population Suppression of Trogoderma glabrum by Using Pheromone Luring for Protozoan Pathogen Dissemination. *Journal of Economic Entomology* **1977**, *70*, 469-474, 10.1093/jee/70.4.469.