Deciphering insect communication in the ecosystem

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1. INTRODUCTION

A number of insects are listed as destructive pests in the agricultural and natural ecosystems: many of them feed on the leaves (e.g. moth caterpillars); borers (e.g. horn beetle and tree borer moth larvae) infest inner bark, sapwood or heartwood of trees; some of them attack fruits by directly feeding on the fruit tissues (e.g. fruit moth larvae, fruit fly maggots). My attention in this symposium will be focused on chemical communications in some fruit eaters, which include economically important taxa, the tortricid fruit moths (Lepidoptera) and the tephritid fruit flies (Diptera). Even a beautiful swallowtail butterflies (Lepidoptera) infest young leaves of citrus plants during the larval stage. In many cases, insects use various arrays of "semiochemicals (signalling substances)" in their life history. For instance, (1) they use "sex pheromones" to recognize the partner in the sequential courtship behavior, (2) females may detect specific fruit odor (kairomones) to lay eggs, (3) and mark fruits with pheromone to avoid multiple oviposition, (4) adults may forage for proteinous or sugary substances, which can be used as a bait in the pest control programs, (5) some insects may positively accumulate noxious plant allelochemicals (allomones) to protect themselves from predatory or parasitic attacks. These insects live in the chemical world. Such ecologically significant signalling substances have been as analysed in some cases as below. I here introduce several examples of pheromone and allelochemical uses mainly in the fruit pest insects.

2. PHEROMONAL COMMUNICATION IN THE ORIENTAL FRUIT MOTH

The Oriental fruit moth, *Grapholita molesta*, is one of the major pests of apples, peaches, pears and other rosaceous fruits. The larvae damage the young twigs, causing them to die in early spring, and the later generations feed inside the fruit rendering them undesirable. Like most other moth species, females of *G. molesta* secrete sex pheromone (female pheromone) to attract males. The female sex pheromone components have been established to be a mixture of *Z*- and *E*-8-dodecenyl acetates, *Z*-8-dodecenol and dodecanol (Cardé et al., 1979). The sex pheromone has been used in the integrated pest management of this cosmopolitan species in various countries; the formulations have been effectively used for monitoring and mating disruption techniques in the integrated pest management. However, not only the female but also the male moth emits sex pheromone (male pheromone) to entice the female, emitting volatile substances from a specific blush-like organs called "hairpencil". Immediately after landing near the calling female, the male turns away and rhythmically extrudes and retracts his abdominal hairpencils, propelling over the female using wind generated by his vibrating wings. The female quickly walks toward the source of the odor and with her head touches the tip of the male's abdomen, evoking from him a copulatory attempt. The whole sequence of the courtship behavior provides an example of chemical communication between both sexes.

The male hairpencil organs are located between the 7th and 8th abdominal segments of the male moths, and are associated with claspers. When extruded, the hairpencils emit a pleasant floral odor, which has appeared to be responsible for the attraction of females. The emission of hairpencil volatiles is accompanied with wind puffs created by wing vibration. Females usually walk upwind and then touched the filter paper treated with crude hairpencil extracts. The male pheromone was identified as ethyl *trans*-cinnamate and methyl epijasmonate (so-called "Queen of Aroma") (Baker et al., 1981). We could decipher their chemical communication between those insects.

3. HOST-FINDING PHYTOCHEMICAL CUES IN BUTTERFLIES

Plants produce a vast array of secondary metabolites as a result, in part, of coevolutionary interactions with phytophagous organisms. A number of insects have not only overcome these chemical barriers and specialized in a limited group of plant taxa, but positively utilize the plant chemicals as cues at oviposition and larval feeding. In recent years, suites of specific oviposition stimulants have been characterized in several families of butterfly species. The oviposition stimulant systems in the citrus swallowtail butterflies *Papilio xuthus,* listed as a pest of *Citrus* plants, have been shown to consist of multiple components, which include flavonoids, alkaloids, amino acid derivatives, nucleosides and cyclitols (Nishida et al. 1987; Nishida, 1995). Complex mixtures of flavonoid glycosides, hydroxycinnamic esters and phenethylamines are commonly used as basic ingredients among 3 *Papilio* species feeding either on Rutaceae or Apiaceae (*P. xutuhus, P. protenor and P. polyxenes*) (Honda and Nishida, 1999). Flavonoids represent one of the most diverse and widespread classes of plant constituents and therefore seem to serve as excellent cues in host recognition not only by the advanced *Papilio* species but also by a primitive papilionid (*Luehdorfia japonica*) (Nishida, 1994). Cyclitols are also used by *P. xuthus* (*chiro-inositol*), *Atrophaneura alcinous* (sequoyitol), and *Battus philenor*. During the food assessment phase of oviposition behavior, such underlying chemical similarities might have opened up a route to colonization of novel hosts (host shift). We need to study further these complex synergistic actions of oviposition stimulants for these related species to understand the chemosensory mechanisms and evolution of the host selection processes mediated by these plant allelochemicals.

Some plants are unacceptable by oligophagous insects in spite of their close botanical relation to host plants. For instance, females of *Papilio xuthus* do not lay eggs on a rutaceous plant, *Orixa japonica*, because of the presence of contact oviposition deterrents, which include a flavonoid glycoside related to their oviposition stimulants (Nishida et al., 1990). These inhibitory factors are also perceived by the chemosensilla on the foretarsi. It is of great interest to examine molecular mechanisms of both stimulatory and inhibitory processes in the tarsal chemoreceptors.

4. CONCLUSION

Chemical messages demonstrated here by the phytophagous insects are only examples of specific ecological interactions. However, if we can accumulate ideas to decipher their language from the complex ecological networks, we may be able to find some ways to understand their evolutionary pathway amongst the interacting organisms and innovative methods how to manage natural and agricultural environments we are facing in this century.

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