Pheromones and other semiochemicals
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Pest repelling properties of ant pheromones

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Abstract: Ants control pests via predation and physical deterrence; however, ant communication is based on chemical cues which may serve as warning signals to potential prey and other intruders. The presence of ant pheromones may, thus, be sufficient to repel pests from ant territories. This mini-review shows that four out of five tested ant species deposit pheromones that repel herbivorous prey from their host plants.

Key words: Ant semiochemicals, pest repellence, insect pests, biological control, IPM, plant protection

Introduction

Ant species have proven to be efficient control agents against a wide range of pest insects in many crops (Way and Khoo, 1992). E.g. weaver ants (*Oecophylla smaragdina* and *O. longinoda*) are known to control more than 50 different pests in 12 different crops and are able to increase farmers' net income with more than 70% when substituting conventional pesticide regimes (Peng *et al*., 2004, Peng and Christian, 2005). As ants are predators of other insects, including herbivores, they can prey on and directly control pest insects. Additionally, however, ant communication is based on chemical cues which may be eavesdropped by potential prey and serve as chemical warning signals or, alternatively, be used by symbionts to stay associated with their ant hosts. The mere presence of ant pheromones may, therefore, be sufficient to repel pest insects from ant territories and the pheromones may serve an important role in the attraction of symbionts that may be essential for efficient plant protection. This is further supported as ants do not only deposit volatile trail pheromones, but also lay out more persistent chemical signals. E.g. weaver ants produce anal spots that are used to navigate and mark their territories. These deposits can be detected by the ants 11 months after they have been deposited, even if they have been washed by rain water (Beugnon and Dejean, 1992). Furthermore, these deposits are not only laid out to reinforce ant trails, but are also distributed throughout the territory of a colony (Hölldobler and Wilson, 1977; Offenberg, 2007) and, therefore, the density of the spots is positively correlated with the likelihood of being detected by an ant (Offenberg, 2007). In conclusion, these deposits seem to be reliable warning signals to potential prey which may, as a result, evolve abilities to detect them and, subsequently, avoid them. If investigated and utilized properly, the semiochemical properties of ant pheromones may thus hold high potential in integrated pest management (IPM).

The study of the effect of ant pheromones on their surrounding insect community is still in its infancy. In this paper, I review the few studies testing the effect of ant pheromones on herbivores and other functional groups of insects and provide support for the potential application of ant pheromones in plant protection.

The effects of ant semiochemicals

Cases where ant pheromones repel herbivores

Initially, it was found that a chrysomelid beetle (*Rhyparida wallacei*) feeding on a mangrove (*Rhizophora mucronata)* was deterred from feeding on leaves that had previously been exposed to the weaver ant *O. smaragdina* (Offenberg *et al*., 2004a; Offenberg *et al*., 2004b). Twenty-one out of 25 beetles preferred to feed on leaves without prior ant presence, and the feeding rate was almost three times higher compared to leaves previously exposed to ants. Based on this finding, it was proposed that indirect mechanisms, where insect herbivores are repelled not only by ants but also by ant pheromones, may be operating between ants and their prey (Offenberg *et al*., 2004b). This idea was subsequently tested in Benin with the related weaver ant *O. longinoda* (Adandonon *et al*., 2009; Van Mele *et al*., 2009); in this case, on the oviposition preference of two fruit flies (*Bactrocera invadens* and *Ceratitis cosyra)* on mango fruits. When offered ant-exposed and unexposed mangoes in the absence of ants, both fruit fly species were reluctant to land on ant-exposed fruits and, when having landed, often took off quickly without ovipositing. The number of fruit fly puparia collected from unexposed mangoes was approximately eight-fold higher than from ant-exposed ones. Furthermore, the results showed that adult fruit flies were more affected through repellence than by direct predation (Van Mele *et al*., 2009).

Two recent studies tested the repelling properties of chemicals deposited by three New World ant species against a flea beetle (*Margaridisa* sp.) on leaves of their host tree *Conostegia xalapensis* (Gonthier *et al*., 2010; Gonthier, 2012). In choice experiments without ants, leaves coated with crushed ant liquids (*Azteca instabilis*), leaves exposed to ant patrolling inside a box prior to choice tests (*A. instabilis* and *Camponotus textor*) and leaves from trees with and without ant nests (*A. instabilis*) resulted in more herbivores and herbivory on control, relative to ant-treatment leaves. In contrast to *A. instabilis* and *C. textor*, leaves previously patrolled by *Solenopsis geminata* showed no difference in beetle numbers and damage, compared to control leaves. As *A. instabilis* control pest insects of coffee (Hsieh and Perfecto, 2012), this species is interesting in relation to biological control and IPM, as in the case with *Oecophylla* spp. ants.

In conclusion, chemical cues from four out of five tested ant species have been shown to repel herbivores and, furthermore, three of these ant species (*O. smaragdina, O. longinoda* and *A. instabilis*) are known to control pests in a number of crops. Lastly, it has been hypothesized that even vertebrates may be deterred by ant chemicals. In feeding trials, African elephants (*Loxodonta africana*) avoided feeding on acacias (*Acacia drepanolobium*) if they were associated with their symbiotic ant *Crematogaster mimosa* (Goheen and Palmer, 2010). Based on this finding and Daniel Janzen's (1983) proposal that livestock can smell the presence of symbiotic ants on Central American bullhorn acacias and in this way avoid these plants day and night, Kwok (2011) suggested the use of synthetic ant pheromones to make elephants steer clear from agricultural lands in Africa. These initial findings on the effect of ant pheromones on herbivores are promising. It therefore seems worthwhile to further elucidate the signaling properties of these pheromones and to test and develop their use in future sustainable pest management.

Cases where ant pheromones affect non-herbivorous prey, competitors and symbionts

Additional evidence for the prevalence of ant pheromones and their significance for insect communities comes from a number of studies showing that other functional groups of insects are affected by their presence. E.g. (i) lepidopteran larvae living as symbionts inside weaver ant nests can follow the trail pheromones of their host ants (Dejean and Beugnon, 1996), (ii)

aphid trophobionts reduce their dispersal rates when they experience hydrocarbons laid passively by their ant hosts (Oliver *et al*., 2007), and (iii) competing ants register a competitor species' pheromones and adapt their foraging behavior accordingly (Dejean *et al*., 2005). Lastly, the coccinellid beetle *Adalia bipunctata,* which in its egg stage is preyed upon by ants, avoid ovipositing on filter paper that has previously been patrolled by *Lasius niger* ants (Oliver *et al*., 2008).

Perspectives

If the deterrent property of ant pheromones on pests is a general phenomenon, further research within this field may lead to the development of a more sustainable pest management. With continued research, chemical ecologist and engineers may be able to identify, synthesize and utilize the active compounds from ant pheromones, or such compounds may inspire the engineering of related molecules with similar repelling properties. Also, further knowledge on the ecology of ant pheromones may help to develop more effective ant management in settings where the ants are used as biocontrol agents. For instance, if ant pheromone persistence is high, it may not be necessary to preserve permanent ant colonies in crops but sufficient to inoculate crops with ants prior to periods with high vulnerability and, subsequently, rely on the presence of the ant deposits to work on the pests. Such modifications in the use of ants in biocontrol could lead to more cost effective management programs.

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