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Impact of host plant on the pheromonal response of phytophagous insects

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Abstract

Morphological and biochemical features of host plants have an impact on survival, feeding, distribution, reproduction and behavior of many phytophagous insects. Chemical communication is most common between the insects and their host plants. The survival and the behaviour of many of the phytophagous insects depends on their host plants. Sex and aggregation pheromones play a major role in their intra-specific communication among the insect species. The behaviour and physiology of insects including pheromonal communication optimizes the mating and reproduction is by the host plant phytochemicals. Host plants aids insects by producing cues to find mating partners, and insects have also developed some tactics to optimize mating for better reproduction using these host plant chemicals. In general, the phytophagous insect pests are a major constraint in the production of agricultural, horticultural crops and plantation too. As many broad-spectrum chemicals are restricted as a result of indiscriminate application, a need to develop better alternative control method with long term sustainability is the need of hour in the management system. Development of pheromone-based lures can be of greater importance in control along with the use of host plant chemicals to enhance or synergize sex attraction of insects. Knowledge on insect behaviour in response to the combinations of their host plant chemicals and their pheromonal communications is important in research and for production of sexual and host plant attractants as a new approach to biologically manage the phytophagous insect pests.

Keywords: Phytophagous insects, host plant attractants, pheromones, insect communication

Introduction

Sex pheromones are signals produced by either of the sex to promote identity and status of sender for attracting a mate. Aggregation pheromones attract both sex to form groups of individuals for the purpose of mating, and for overwhelming their predators^[10]. Both the sexual and aggregation pheromones are released for intra-specific communication by insects. Some of the insects produce their pheromones or its precursors from their host plant chemicals through sequestration. While in some, production and release of pheromones is in response to their specific cues from host plant. In certain category, the chemicals from host plants synergizes the emission of pheromones or enhances the response of an insect to the pheromones^[18].

This review briefly highlights on the insects host plant relationship, communication, sequestration of chemical for enhanced attraction towards mating and survival.

Production and release of pheromone

Production of pheromones by acquiring the bioactive chemicals or the chemical precursors of pheromones by consumption, absorption or inhalation of host plant material. Stimulating pheromone production and release by the host plant kairomones acting on nervous and hormonal system of insects^[18].

Insect larval sequestration

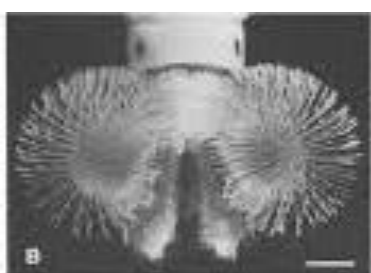
It is the segregation of plant secondary metabolites and stored within the body as a self defence against their own natural enemies.

Larval stage acquires the plant compounds feeding on host plant and sequester them for their communication during adult stage. The sequestration of host plant chemicals by the larval stage and using as sex pheromones in adult stage was first reported in Oak leaf roller (*Archips semiferanus*)^[12]. Arctiid moth (*Utethesia ornatrix*) males produce a courtship pheromone hydroxydanaialal derived from monocrotaline which is a pyrrolizidine alkaloid (PA) ingested

during larval stage from its host plant genus *Crotalaria*.^[8] Pyrrolizidine alkaloids are a group of naturally occurring alkaloids found mostly in the plants belonging to the families boraginaceae, asteraceae, orchidaceae and fabaceae and less frequently in the families of convolvulaceae poaceae and lamiaceae. They are produced by plants as a defence mechanism against insect herbivores^[38].



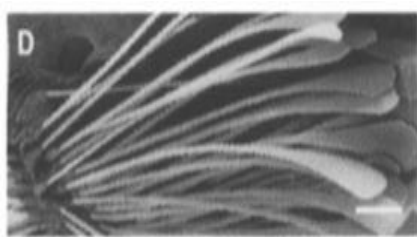
Utethesia ornatrix moth



Coremata

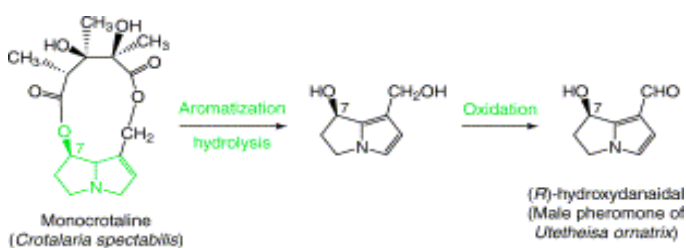


Smaller coremata scales at base of primary scales of male



Enlarged view of primary coremata scales

(Conner *et al.*, 1981)



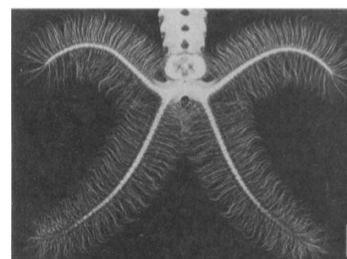
(Reddy *et al.*, 2000)

Males of arctiid moth (*Cretonotus gangis*) produces a sex pheromone hydroxydanaidal by the sequestration of

compounds from pyrrolizidine alkaloids (PA's) from their host plants. They release and attract their opposite sex by averting their coremata tubes^[29].



Cretonotus gangis moth displaying its coremata tubes



Coremata tubes

(Schneider *et al.*, 1982)

Female confirm the ability of their opposite sex in providing protection by means of the quality of pheromone volatiles. In giant danaine butterfly (*Idea leuconoe*), males display their 'hair-pencils,' which are a pair of brush-like glandular organs which release volatiles for attracting opposite sex during courtship. The hair-pencil volatiles are composed of mixture of danaidone and viridifloric β lactone. These two compounds are the fragments of pyrrolizidine alkaloid, lycopsamine sequestered from its host plant, (*Prosopis laevigata*)^[23]. In oriental fruit moth (*Grapholita molesta*) males releases herbal scent by displaying hair-pencil, which is a mixture of methyl epijasmonate and ethyl (E) cinnamate, acquiring from their host plant tissue during larval stage by sequestration to attract conspecific females as a courtship pheromone^[2].

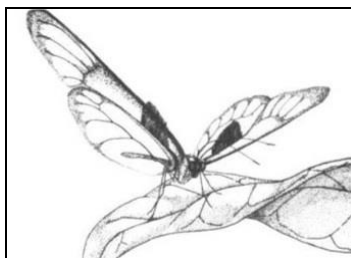
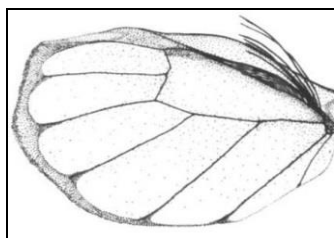
Insect adult sequestration

Males of arctiid moth (*Cisseps fulvicollis*) synthesize a sex attractant hydroxydanaidalin by sequestering the pyrrolizidine alkaloids, while feeding on dead and damaged plants and release by averting their coremata^[16]. These PAs not only attracts their opposite sex but also attracts other males to their host plants.

In Ithomiine butterflies of nymphalidae, males get attracted and feed on plants containing pyrrolizidine alkaloids, undergo sequestration and use them as precursors of sex pheromones and releases pheromone by averting their hair-pencils^[25].

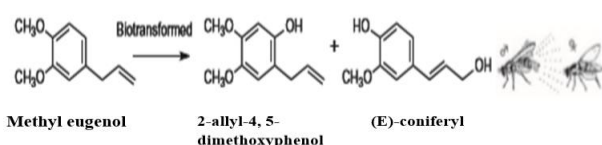


Ithomiine butterfly

Male *Pteronymia nubivaga* on perch with erected hair-pencilsCostal hair-pencil of *Pteronymia beebei*
(Pliske *et al.*, 1975)

The Euglossini, also called as "orchid bees," or "gold bees," males collect the chemicals which are a mixture of terpenoids from orchids by scraping the wax from flowers by their fore tibia and store it within the pouch like structures on hind tibia and use them as a sex attractant^[36].

In oriental fruit fly (*Bactrocera dorsalis*), the males feed on methyl eugenol present within the flowers and acquire the defensive plant chemicals pharmacophagously by foraging during adulthood and sequester metabolites, 2-allyl-4, 5-dimethoxyphenol and (E)-coniferyl alcohol selectively within the rectal glands to deter feeding by their predators. This metabolic by-product appears to make up a part of the sex pheromone. Sexual selection by the females in these flies are strongly interconnected with the defensive fitness properties of male flies^[23].

(Nishida *et al.*, 2014)

Bark beetle (*Ips paraconfusus*) (Coleoptera: Curculionidae) males uses myrcene from their host tree ponderosa pine (*Pinus ponderosa*) as a precursor to produce aggregation pheromones ipsenol and ipsdienol. Symbiotic bacteria which is restricted to males is involved in the oxidation of myrcene. In this, aggregation pheromone also comes under sex pheromone due to a role other than insects getting attracted for food also attracts for mating^[7]. Males of mountain pine beetle (*Dendroctonus ponderosa*) (Curculionidae: Coleoptera) releases an aggregation pheromone trans-verbenol by acquiring a compound alpha-pinene as a precursor from their host tree ponderosa pine^[13].

Pheromone production by the host plants

Host plants plays an important role in biosynthesis of pheromone in insects. In females of corn ear worm (*Helicoverpa zea*) the synthesis of pheromone is activated by the volatile chemical signals from the solvent extracts of corn silk which triggers the production of pheromone biosynthesis activating neuropeptide which originates in the sub-

oesophageal ganglion and is released through the corpora cardiaca and activates the bio-synthesis of pheromone^[26].

Pheromone signalling and release by the host plants

African palm weevil (*Rynchophorus phoenicis*) (Curculionidae), acquires a mixture of volatile esters from its host tree oil palm (*Elaeis guineensis*), within the volatiles a compound ethyl acetate induces the males to release its aggregation pheromone (E)-6-methyl-2-hepten-4-ol (rhynchophorol). In females of pink bollworm, cabbage looper, Caribbean fruit fly the release of sex pheromone depends on the surface of the plant a morphological feature, they mark the pheromone by rubbing with their abdomen to slow down the release to atmosphere and increase the amplitude of plume^[17]. The presence of host plant seeds plays a role in stimulating the release of pheromone by the females of the cowpea weevil (*Callosobruchus maculatus*), as it was evidenced by the increased male electroantennogram response to the airflow over the females provided with seeds^[19].

Pheromonal response by the host plant volatiles

Pheromones acts synergistically when pooled with the host plant volatiles^[32]. Host plant volatiles elicit a positive effect on the behaviour of insects responding to sex pheromones released in association. It results in synergism, in which the response to the mixture of pheromone and host plant volatiles is greater than the pheromone alone.

First report on synergistic action is, alpha-pinene a main monoterpene in southern yellow pine with frontalinal, a major component of an aggregation pheromone of southern pine beetle (*Dendroctonus frontalis*)^[28]. In males of African palm weevil (*Rynchophorus palmarum*), ethyl propionate a constituent of its host tree oil palm, acts as a synergistic kairomone which enhances the attraction of adults to its aggregation pheromone "phoenicol" (3-methyl-octan-4-ol)^[14]. Mixtures of green leaf volatiles (GLVs) from cabbage (Z)-3-hexenyl acetate, (E)-2-hexenal, (Z)-3-hexenol with the pheromone [a mixture of (Z)-11-hexadecenal, (Z)-11-hexadecenyl acetate, (Z)-11-hexadecenol] induced a significant higher attractant arresting behaviour in unmated males of the diamondback moth (*Plutella xylostella*) than the pheromone alone^[27]. Corn the utmost preferred host crop of corn ear worm (*Helicoverpa zea*) emits high levels of (Z)-3-hexenyl acetate during the tasseling stage through the silking stages. Sex pheromone traps containing the host plant compound (Z)-3-hexenyl acetate, significantly increased the capture of corn ear worm males as 104 male moths caught during pre-tasseling to silk stage and 123 males got caught during silking stage to kernel stage of maize crop^[20].

In Ambrosia beetles of the genus *Gnathotrichus*, male produces pheromones like racemic 6-methyl-5-hepten-2-ol ((+)-sulcatol) and S-(+)-sulcatol, which are synergistically enhanced by the host-derivative compounds alpha-pinene and ethanol^[6]. In maize weevil (*Sitophilus zeamais*), weevils respond significantly more to male-produced pheromones Sitophinone along with broken wheat grains than the pheromone alone^[37]. The numbers of males caught in traps baited with synthetic female sex pheromone with corn extract were significantly higher than those caught in traps baited with pheromone alone in angoumois grain moth, (*Sitotraga cerealella*)^[33]. In smaller European elm bark beetle, (*Scolytus multistriatus*), the pheromonal compound multistriatin and 4-methyl-3-heptanolare synergized by the host compound alpha-cubebene^[11].

Traps baited with the aggregation pheromone of strawberry blossom weevil (*Anthonomus rubi*), and a volatile from strawberry flowers, 1, 4 Dimethoxybenzene (DMB), the sex pheromone of European tarnished plant bug, (*Lygus rugulipennis*) and the host-plant volatile, Phenyl acetaldehyde (PAA), attracted both targeted insect pest species to the same trap^[3]. The plant blend containing a mixture of three green leaf volatiles like [(Z)-3-hexenyl acetate, (Z)-3-hexenol, and (E)-2-hexenal] and two aromatics [benzaldehyde (BZA) and benzonitrile (BZN)], increased the attraction of males of oriental fruit moth (*Grapholita molesta*) to a suboptimal dose (2 ng) of synthetic female sex pheromone, composed of (Z)-8 dodecenyl acetate (Z812:Ac), (E)-8 dodecenyl acetate (E8-12:Ac), and (Z)-8 dodecen-1-ol (Z8-12:OH) in an experiment conducted in a wind tunnel^[34].

Conifer volatile alpha-pinene released at high rate synergized the attraction of conifer-infesting beetle species in the subfamilies Spondylidinae and Lamiinae, to the pheromone blend containing racemic 3-hydroxyhexan-2-one, (2R*, 3R*)-2, 3-hexanediol, racemic fuscumol, racemic fuscumol acetate, monochamol, and racemic 2methylbutanol^[21]. In the presence of the host plant either physical contact or olfaction of the plant volatiles, virgin and mated females of (*Tuta absoluta*) too produced higher amounts of the major component of the pheromone (TDTA) (E3, Z8, Z11)-tetradecatrien-1-yl acetate (E3, Z8, Z11-14:Ac)^[1].

The process of aggregation in western pine beetle, (*Dendroctonus brevicomis*) (Coleoptera: Scolytidae), on a ponderosa pine tree, begins when a female making the entrance hole and begins excavating a nuptial chamber and tunnelling inside the phloem tissue. A component of the aggregation pheromone, exo-brevicomin, is synthesized during boring and feeding within the tree is released by defecation by the female and causes a low-level attraction of females as well as males. After the male joins the female in the nuptial chamber, immediately releases frontalin which is more attractive along with exo-brevicomin in a synergistic manner^[30].

Antennal eletro-physiological response of chrysomelid beetle (*Phyllotreta striolata*) an important pest of brassicacea to their host plant (*Cendrus atlantica*) and (*Brassica juncea*) volatiles alkenyl glucosinolate hydrolysis products, allyl isothiocyanate, 4-Pentenyl isothiocyanate and green leaf alcohols (Z)-3 hexenol and 1-hexanol and male specific sesquiterpenes (+)-(6R, 7S)-Himachala-9, 11-diene elicited antennal response in both males and females^[5]. From lab and field experiments it was concluded that pheromone is attractive when there is a simultaneous presence of host plant volatiles. Eg: AITC (Ally Isothiocyante) triggers the behavioural response of (*Phyllotreta striata*) beetles to aggregation pheromone.

It was reported that AITC, is a breakdown product of glucosinolates in Rape seed plant (*Brassica napus*) a host plant of flea beetle (*Phyllotreta cruciferae*) attracted both the sexes of flea beetle along with the combination of male specific pheromonal recemic compounds^[31]. Similarly, multiple funnel traps baited with quaternary blend of two host volatiles like ethanol and alpha-pinene and two pheromones of bark beetle like ipsenol and ipdienol attracted greater number of *Monachamus* spp in pine forests of North America^[22]. Wild oriental fruit fly (*Dacus dorsalis*) males from Malaysia accumulates 10 µg of Methy eugenol metabolite 2-allyl-4, 5-dimethoxyphenol from their host plant in their rectal gland and release this metabolite in to air during dusk which

is highly attractive to the conspecifics males which acts as an aggregation pheromone^[24].

From investigation, electrophysiological response of legume pod borer (*Maruca vitrata*) which is a serious pest of cowpea, using male and female antenna to the host plant compounds (Z)-3-hexenal, (E)-2-hexenal, (Z)-3 hexen-1-ol, and 1-octen-3-ol. Among all 1-Octen-3-ol was the major cowpea volatile detected antennally and also increased the calling from females. Major pheromone component is (E, E)-10, 12-hexadecadienol^[4].

A blend of four volatiles of *Vitis vinifera* c.v. *solaris* (1-hexenol, 1-octen-3-ol, (Z)-3 hexenyl acetate and (E)-B-caryophyllene) mixed at ratio based released in wind tunnel at 10,000 pg/min attracted more number of males of European grape vine moth (*Lobesia botrana*) indicating host plant volatiles acts as olfactory cues and males get attracted to encounter females^[35].

Conclusion

Chemical communication being the most significant criteria between the insects and their host plants paved way to improvise pest management strategies. Pheromonal lures based on attract and kill have become more important now-a-days in insect pest control as it disrupts the mating and reproduction of their progenies. Host plant compounds have a greater impact on the chemical communication in many of the phytophagous insects belonging to the families of the Coleoptera, Lepidoptera, and Diptera. In the management of pests, the synergistic effect of both the pheromones and the host plant combinations volatiles proven to be far better than the effect caused by pheromones alone. Modifying the pheromonal lures with the host plant compounds can maximize the attraction of insect pests. Therefore, this innovative pest control approach may increase the crop productivity by preventing the damage caused by insect pest thus maintaining food and nutritional security.

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