



# Impact of Plant on Insect Behavior and Sex Pheromone Emission

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Insects intricately interact with host plants, significantly impacting their behavior and chemical communication, especially in phytophagous species. Insect physiology and behavior, particularly sex pheromone communication, are influenced by host plants, which improves mating and reproduction. While some insects release sex pheromones in response to cues from plants, others use the molecules of their host plants to synthesize sex pheromone precursors.

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Host plants chemicals synergize with sex pheromones, aiding in insect communication and reproductive success. These interactions shape various aspects of insect behavior, from aggregation formation to mate and host finding strategies, and even reproductive isolation among related species. Understanding these relationships is essential for comprehending ecological dynamics and devising sustainable pest management strategies.

**Keywords:** Behavior; flower; fruit; gustatory cues; herbivores; host plant; leaf volatiles; olfactory cues; parasitoids; pheromones; plant volatiles; synergism.

## 1. INTRODUCTION

Insects use olfactory, visual, and gustatory cues to select and feed their hosts. This method uses neurosensory receptors in insect and plant-produced semiochemicals to distinguish between host and non-host. These interactions are long-term associations between insects and plants for fitness purposes. Some plant chemical compounds affect insect physiology, behavior, and sexual communication during mating [1]. Here, the host plant's chemicals regulate, mediate, or increase insect sexual communication [2]. Certain insects store or acquire host plant metabolites, which they then use as precursors or sex pheromones. Female phytophagous insects produce the sex pheromones containing plant volatiles. Insects generate both sexual and aggregation pheromones for intraspecific communication. Some insects use sequestration to manufacture pheromones or precursors from the compounds in their host plants. While in some, pheromones are produced and released in response to specific cues from the host plant. In some cases, compounds from host plants synergize pheromone emission or increase an insect's reaction to pheromones [3]. Herbivores' natural enemies also employ plant volatiles to find food, in addition to herbivorous insects that use them to identify their hosts [4]. Plant volatiles may help these insects discover mates in addition to species-specific pheromones, according to mounting evidence [1]. Insects that are looking for mates typically visit plant characteristics including flowers, fruit, and leaves. Insects can be successfully directed to these regions by the combination of plant volatiles and pheromones, where they can locate food and potential mates [4]. The fact that plant volatiles can generate sex pheromones, which increases an insect's receptivity to potential mates [4], supports this theory. Aspects of feeding and mating aggregation formation, insect strategies to locate both hosts and mates, behavioral reproductive isolation among sibling species, and reproduction regulation to coincide with the

availability of food and oviposition sites are all potentially impacted by host plant influences on insect sex pheromone communication [2]. In recent years, researchers have looked into how different phytophagous insects behave differently in reaction to plant volatiles depending on their sex, maturity, and mating status [5]. Mature female *Bactrocera tyroni* (Froggatt) fruit flies (Diptera: Tephritidae) were more drawn to the volatiles in their host fruit than were unmated females [6]. Males were attracted to the smells of unripe fruits, but both mated and unmated female *Neoceratitis cyanescens* (Bezzi) (Diptera: Tephritidae) tomato fruit flies responded to ripe tomato fruits [7]. After mating, female moths of the cotton leafworm *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae) shift from preferring the scents of flowers to those of plants utilized for oviposition [8]. Understanding these connections is essential to comprehending a wide range of topics related to the behavioral ecology of insects that feed on plants.

## 2. HOST PLANT MECHANISMS THAT AFFECT SEX PHEROMONE BEHAVIOR

The effects of host plants on the biology of phytophagous insect sex pheromones can be separated into two categories. These effects could be on the pheromonal signaler or on how the insect recognizes and reacts to the pheromone through behavior [2].

- Experiments have shown that influences on the signaler can result in enhanced pheromone production or release, as well as elicitation of the specific behavior or calling posture.
- Behavioral assays are commonly used to quantify pheromones, and variations in insect reactivity to these signals are indicative of responder influences.

Moreover, prior to pheromonal communication, insects may exist at or on host plants for certain species, as mentioned by Shorey, [9]. In certain

situations, there may be a connection between the host and sexual communication, but the host may not directly influence sex pheromone activity.

### 3. PLANT VOLATILES AFFECTING SIGNALING AND PHEROMONE PRODUCTION

- Stimulation
- Synergism
- Additives

#### 3.1 Stimulation

A number of phytophagous insects only begin to release pheromones or exhibit enhanced mating behaviors in response to the host plant's scent [4]. When palm weevil males *Rhynchophorus palmarum* are exposed to volatile ethyl acetate found in the host plant, they emit an aggregation pheromone [10]. When female cowpea weevils *Callosobruchus maculatus* (Fabricius 1775) encounter host-plant seeds, they emit more pheromones [11]. Research suggests that male tephritid flies (Diptera: Tephritidae) are more likely to mate when exposed to volatiles from host plants [12,13]. When exposed to cotton or cabbage plants, both male and female cabbage looper moth *Trichoplusia ni* appear to create more sex pheromones, suggesting that this generalist insect searches for a host plant prior to engaging in mating behaviors. The female *Helicoverpa zea* corn earworm waits to reproduce and release their pheromone until they locate a maturing ear of maize on which to lay their eggs [14]. The resource-based mating strategies of phytophagous insects effectively integrate the search for a reliable mating site with the oviposition of a suitable host plant [4]. The South American fruit fly, *Anastrepha fraterculus*, is one notable fruit pest. Males of this species are encouraged to engage in sexual activity by the smells released by *Psidium guajava*, or guava, fruit, which is one of their main hosts. Compared to men who were unaware of the scent of fruit, excited males release more pheromone and participate in sexual displays more frequently [1]. The way that mature insects behave in reaction to volatile substances released by plants differs depending on the gender. Modulations in the peripheral or central neural systems may be the cause of these variations in behavioral reactions [5]. It is interesting to note that ethylacetophenone, an appealing flower volatile, elicited stronger responses in immature than in mature flies of the

cabbage root fly, *Delia radicum*, whereas allyl isothiocyanate, a compound stimulating oviposition behavior, elicited stronger responses in mature than in immature flies. These findings are consistent with the behavioural roles of these compounds. Differential antennal sensitivity to behaviorally active chemicals was demonstrated by a number of host-derived compounds that elicited stronger reactions in females than in males and, at least at high doses, stronger responses in mature flies than in immature flies [5].

#### 3.2 Synergisms

Integrated pest management (IPM) research is the clearest source of evidence that host-plant volatiles work in concert to enhance pheromone attraction. Research has repeatedly demonstrated that while traps containing solely plant volatiles are not very appealing, those containing both plant volatiles and pheromones are more effective in capturing the pests. Numerous agricultural pests, including Hemiptera, Coleoptera, and Lepidoptera, are known to exhibit this phenomenon (Rochat et al., [15]. The male longhorn beetle (*Anaglyptus subfasciatus*) [16,17], the male tobacco budworm (*Heliothis virescens*) [18,19], the male codling moth [20], and the grapevine moth (*Lobesia botrana*) [21] have also been reported to exhibit this type of synergism by plant volatiles. Furthermore, in male *Helicoverpa zea* insects, host plant volatiles strongly synergized sex pheromone-specific olfactory receptor neurons (Phe-ORN) responses [22,17]. When many of these insects are seated on the fruits, flowers, or leaves of host plants, they usually release pheromones that combine to create a much bigger overall odor plume [12, 23, 24, 25]. A plume that combines pheromones and plant volatiles may be more effective at guiding and attracting potential mates than one that merely contains one of the two components. This combination might work well for the stepwise mate location described below. The pheromone comes from a point source, not the massive plume that a whole plant produces (a pheromone gland) [4] (Fig.1). *Cnaphalocrocis medinalis* can be individually trapped by host-plant volatiles and sex pheromones. The electroantennogram response of *C. medinalis* to sex pheromones was enhanced by the addition of (E)-2-hexenal, methyl salicylate, valeraldehyde, and (Z)-3-hexenal [26]. According to field assessments, combining sex pheromones with (E)-2-hexenal /methyl salicylate produced noticeably larger catches of

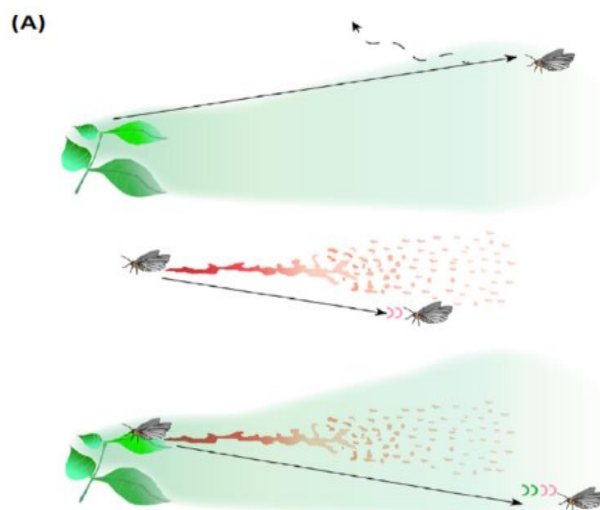
male moths than using sex pheromones alone (Du et al., 2022). Despite being released into an atmosphere of plant odorants, sex pheromones are thought to draw insects on their own. The female pheromone in codling moths, which feed on apples and pears, is effective at attracting males only when the host plant's aroma is present [27]. More Asian Longhorn Beetle ALB adults are attracted to the combination of host volatiles and sex pheromones than to the control [28].

### 3.3 Additives

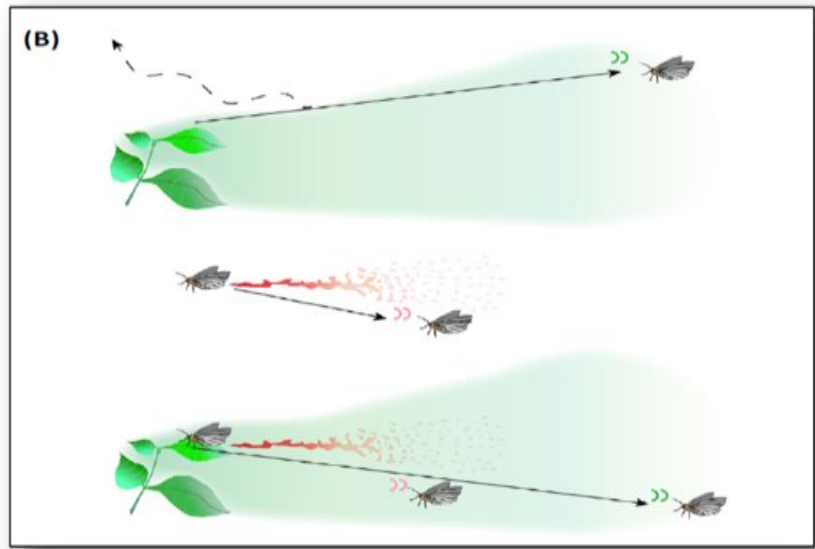
The attraction that results from combining plant volatiles with pheromones is not greater than the total attractiveness of the individual components. This is in contrast to the previously mentioned examples of synergism, where plant volatiles alone for some insect species [4, 17] are already very attractive to male and female herbivores. This is anticipated and observed in female phytophagous insects [16], most likely due to the fact that females, including virgin females, employ volatiles from host plants to choose oviposition sites [2]. In wind tunnel tests, it has been discovered that virgin males of African cotton leafworm *Spodoptera littoralis* are highly attracted to both virgin females and the volatiles found in cotton plants. Once males have mated, the attractiveness of the volatiles in cotton plants rapidly reduces, suggesting that the primary purpose of the initial attraction is to locate females. GLVs, which are normally released

while female cockchafers feed, are more attractive to males than female pheromones in field. This seems that whereas pheromones are utilized to find females at a relatively limited range, GLVs serve as long-range attractants for them Kromann et al., [29].

Additional proof of an additive effect has been documented in relation to parasitoid feeding. HIPVs have been discovered to highly attract virgin braconid parasitoids of both sexes [30]. In fact, it appears that certain solitary parasitoid species do not generate a long-range pheromonal signal. According to Dicke et al. (2009) and De et al. (2013), HIPVs are typically released in host-related particular quantities and with host-related specificity [31, 32]. As so, they might offer parasitoids extremely trustworthy mate-finding information. When the pheromones of different insect species—such as parasitoids and herbivores—are weak or comprise heavy molecules that are readily absorbed into plant tissues, the additive effect of pheromones can be very significant. In other cases, however, pheromones may only function as contact cues that the emitters intentionally deposit on plants [33, 34]. Pheromones that have been deposited or absorbed on a host plant may therefore function as gradually released territorial markers [35]. The placement of the pheromonal cues should be substantially assisted by insects initially hunting using signals supplied by plants [4] (Fig. 2).



**Fig. 1. A mateseeking insect is not or barely attracted by plant volatiles (green) alone but is strongly attracted by the pheromone (red). When the pheromone is released in a background of plant volatiles, the attractiveness of the mixed plume increases [4]**



**Fig. 2. Both plant volatiles and pheromone are strongly attractive to a mate-seeking insect, but at close range it responds only to the conspecific pheromone to pinpoint a potential mate on the plant [4]**

#### 4. PLANT VOLATILES

Plant volatiles are the metabolites that plants release into the atmosphere. The amounts released are not insignificant. Every day, volatiles, which comprise over one-fifth of the CO<sub>2</sub> in the atmosphere that land plants have fixed, are released back into the environment. Plants are champion synthetic chemists because they employ their anabolic process to produce volatiles, which they use to interact with mutualists and competitors equally and protect against biotic and abiotic stressors (perhaps spreading misinformation) [36] (Table 1). Additionally, plants produce a wide variety of volatile chemicals and make up a sizable portion of the natural habitat for moths [17]. Plant species determine which volatile chemicals are emitted, and certain plants may release different compounds based on their physiological condition [37] or their circadian rhythm [38]. Phytophagous insects find oviposition sites, homes, and food supplies in the volatiles of their host plants [39]. Through the perception of specific signals, habitats produce an unpredictable odorant backdrop that can interact in a variety of ways, either enhancing or inhibiting reactions to the pheromones produced by females. An early investigation on green leaf volatiles, for instance, found that the boll weevil, *Anthonomus grandis*, responded more favorably to an aggregated pheromone (grandlure) than to the grandlure pheromone alone [40, 17].

#### 4.1 Leaf-Produced Volatiles

Since host plants are prime locations for mating, the volatiles released by leaves are crucial indicators for phytophagous insects to discover conspecifics of the opposite sex as well as food supplies [48]. There is a lot of evidence that herbivorous insects employ sex pheromones and plant volatiles together to locate potential mates. Results from wind tunnel assays [49, 50] indicate that males of the grapevine moth *Lobesia botrana* and the grape berry moth *Eupoecilia ambiguella* are more attracted to conspecific female pheromones when presented in combination with volatiles found in the host plant, such as sesquiterpene (E)-b-caryophyllene. Plant volatiles have also been shown to boost the attraction of beetle species' aggregation or sex pheromones in the field, with bark beetles being particularly well investigated (Landolt and Phillips, [2]. Aphid traps produced similar results. Plant volatiles are likely to have a favourable influence on mate recruitment that goes beyond direct attractiveness. It has been suggested that adult insects, such as male and female cabbage looper moth *Trichoplusia ni* [4], may secrete more pheromones when exposed to plant volatiles. In the laboratory (wind tunnel) and in the field, Reddy and Guerrero [41] investigated the behavioral reactions of the diamondback moth, *Plutella xylostella*, to green leaf volatiles (GLVs) of *Brassica oleracea* subsp. *capitata*. The results showed that controlling insect pests may depend on the diamond back

moth's ability to attract more males and females to traps baited with pheromone mixed with the reasonably priced and environmentally safe (Z)-3-hexenyl acetate [41].

#### 4.2 Fruit Volatiles

It's reasonable sense that fruit volatiles would attract insects that eat on fruit. Fruits serve as both a food source and a good place for mating for these insects. Fruit volatile mixes can trigger mating behaviors and calling (pheromone release), indicating possibilities for mating. For instance, after being exposed to the volatiles in the host fruit, females of certain tephritid fruit fly species (Diptera: Tephritidae) exhibit greater receptivity to mating [12, 13, 51]. In the papaya fruit fly *Toxotrypana curvicauda*, it was discovered that papaya extracts enhanced the male pheromone's attractiveness to virgin females [43]. Volatiles from ripe corn ears, such as ethylene, incite females' calling behaviors in the maize earworm moth *Helicoverpa zea*, which increases pheromone output [14, 4].

#### 4.3 Flower Volatiles

In addition to drawing pollinators, flower fragrances also function as kairomones, which

are advantageous to the recipient but harmful to the emitter and draw in carnivores (Lucas, 2016) [52]. Due in part to the volatiles in flowers, which cause pollinators and florivores to emit more pheromones and/or become more receptive, these insects often mate on flowers. Nocturnal plant bugs of the genus *Neella* (Hemiptera: Miridae) identify Araceae flower pollen as food by using the distinctive flower scent cis-jasmone [53]. These insects mate mostly on flowers. *Anthonomus rubi*, the strawberry blossom weevil, uses 1,4-dimethoxybenzene, a distinct flower volatile, in combination with other flower volatiles to increase its attraction pheromone. Females of longhorn beetle *Anaglyptus subfasciatus* were attracted to a combination of male pheromones and the flower volatile methyl phenylacetate than to either of the two alone [16]. Tengo et al. [54] found that floral colour and volatiles both seemed to be important factors in drawing in males. Some fruit fly and moth species seem to be among the phytophagous insects that wait until they find a suitable host plant to display strong pheromone emission or to engage in all of their mating rituals. This may allow the insects to release a combination of their pheromones against a background of odors from host plants, which attracts mates especially from conspecifics of the other sex [4].

**Table 1. Host-plant volatiles that affect pheromone synthesis and help insects find mates (Xu and Turling, 2018) [4]**

Order	Insect sp.	PV/plant tissue	Pheromone production (M/F/A)	Affect of plant volatile	Reference
Lepidoptera	<i>Helicoverpa zea</i>	Ethylene (Fruit) and linalool; (Z)-3-hexenol; (Z)-3-hexenyl acetate; corn-silk volatiles	(Z)-11 Hexadecenal; Hexadecanal; (Z)-9-hexadecenal (F)	Stimulant Synergist	Ocheing et al., [22]
	<i>Plutella xylostella</i>	(Z)-3-Hexenyl acetate	(Z)-11-Hexadecenal; (Z)-11-hexadecenyl acetate (F)	Synergist Additive	Reddy and Guerrero, [41]
Coleoptera	<i>Anthonomus grandis</i>	(E)-2-Hexen-1-ol	Grandlure I, II, and III (A)	synergist	Dickens; Dickens et al., [40, 42]
	<i>Rhynchophorus palmarum</i>	Ethyl acetate; isoamyl acetate	(E)-6-Methyl-2-hepten-4-ol (A)	Stimulant Synergist	Rochat et al., [15]
Diptera	<i>Toxotrypana curvicauda</i>	Papaya fruit extract	2-Methyl, 6-vinylpyrazine (M)	Not tested	Landolt et al., [43]
	<i>Ceratitis capitata</i>	(E)-2-Hexenal; tea oil; ginger root oil	Not detected (M)	Stimulant	Dickens et al., Juan et al., Shelly and Epsky, [42, 44, 45]
Hemiptera	<i>Rhopalosiphum padi</i>	Benzaldehyde; methyl salicylate	(1R,4aS,7S,7aR)-Nepetalactol (F)	Synergist	Pope et al., [46]
Hymenoptera	<i>Cotesia glomerata</i>	HIPVs	Female	Additive	Xu et al., [30]
	<i>Microplitis mediator</i>	HIPVs	Aggregation	Additive	Xu et al., Yu et al., [30, 47]

## 5. PARASITOID WASPS AND HERBIVORE-INDUCED PLANT VOLATILES (HIPVS)

HIPVs are used by parasitoid wasps to locate hosts [55]. The main focus of studies on parasitoid mating systems has been the rearing of these crucial biological control agents. The utilization of pheromones in mating selection and acceptance has been the subject of these investigations [56]. However, it appears that some parasitoid wasps do not produce pheromones, or that they only function at a few centimeters' distance [57]. Other parasitoids release high molecular weight pheromones that are only activated in response to physical touch [58, 59]. This implies that these species, especially solitary parasitoids, must use other cues to find mating partners. In fact, we discovered that HIPVs substantially attracted virgin males and females of various braconid wasp species [30]. In order to find their host-damaged plants as meeting places, these parasitoids may rely on plant volatiles. From there, they can use pheromones, such as contact pheromone, for close-range mating activities. This may also explain the mate-seeking behaviors reported for other parasitic wasps. For instance, when females of *Cotesia plutellae* and *Campoletis sonorensis* were placed on a host food plant (either injured or intact), the males found the females more readily. Certain parasitoids may attract both sexes when they smell fruit, whether or whether it is infected, that could be their host. This is the case for the braconid parasitoids of tephritid fly larvae, *Psytalia concolor* and *Diachasma alloeum* [60]. Therefore, a growing body of research suggests that herbivorous insects are not the only ones that use plant volatiles to find mates [4]

## 6. PHEROMONE PRODUCTION AND RELEASE

According to Fang et al. [17], sex pheromones (SPs) are pheromones that a creature releases to entice another organism of the opposite sex for mating and reproduction. In the majority of insects, including moths, females release sperm particles (SPs), which are primarily utilized for reproduction, enticing the opposite sex, and communicating with other members of their species. Pheromone olfactory receptor neurons (Phe-ORNs) in the male antenna detect Sp information, which is subsequently sent to the

macroglomerular complex (MGC) in the antennal lobe for pheromone processing. According to a recent study, the presence of plant volatiles as a background changed the neural and behavioral responses to sex pheromones (Dupuy et al., 2017) [61]. Theoretically, SPs that attract the opposing sex can be employed to effectively control pests. It has been demonstrated that using SPs to attract and trap insects can reduce pest populations in the future, and new insect SPs are always being discovered. For instance, in 1973 Tamaki et al., [62], it was determined that the two species of *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) were (9Z,11E)-9,11-tetradecadienyl acetate (Z9E11-14:OAc) and (9Z,12E)-9,12-tetradecadienyl acetate (Z9E12-14:OAc). According to field research on various ratios of the two SP components, using ten virgin females and one male, a ratio of 10:1 produced nearly the same trap and bait results [63, 17]. Sex hormone production and release may be impacted in a number of ways by the presence of host plant material, both directly and indirectly. Through the eating, absorption, or inhalation of host plant material, several phytophagous insects acquire the necessary chemical precursors of pheromones as well as bioactive compounds, which in turn contribute significantly to the creation of their sex pheromones. Pheromones and host plant chemistry have a close link since certain species transfer and release pheromones through excrement. Pheromone release and eating may be correlated both spatially and temporally in these species. Additionally, plant kairomones may influence insects' neurological and hormonal systems to promote the release and synthesis of pheromones in both male and female insects [2].

### 6.1 Larval Sequestration of Plant Chemicals

In order to protect themselves against their own natural enemies, plants separate their secondary metabolites and store them within their bodies. The plant chemicals are acquired by the larval stage while feeding on the host plant, and they are then stored for use in communication by the adult stage. The oak leaf roller (*Archips semiferanus*) was the first species to be documented to sequester chemicals from its host plants during its larval stage and use them as sex pheromones in its adult stage [3].

Further research on numerous genera of arctiid moths and several species of nymphalid butterflies provided ample evidence that males

use secondary plant compounds for sex appeal or courtship interactions. Male *Utetheisa ornatix* (Arctiidae) insects have a courtship pheromone called hydroxydanaidal, which is produced when the larval plants of the genus *Crotalaria* ingest pyrrolizidine alkaloids (PAs) [64]. The chemicals provide similar protection to eggs and adults and are sequestered by larvae as a protective tactic [2]. There seems to be a comparable connection between moths and the defensive chemical of the host plant in multiple additional *Arctiidae* genera. Males of the *Cretonotos transiens* and *Cretonotos ganges* species produce hydroxydanaidal in coremata tubes that are everted to attract females [65]. Like *U. ornatix*, PAs are required in the diet for *Cretonotos* spp. to make hydroxydanaidal. Male *Grapholita molesta* moths use ethyl-trans-cinnamate as a courting pheromone in hairpencil displays, having sequestered it from host tissue during their larval stage [2].

## 6.2 Adult Acquisition of Plant Compounds

It appears that PAs from plants are collected by the male *Cisseps fulvicollis* moths and used as precursors to produce a sex pheromone. Adults in this species consume injured and dying plants that release PAs into the environment. Males seem to be drawn to plants by the same pyrrolizidine alkaloids, and females by them. In their eversible coremata, males convert these PAs into hydroxydanaidal, which they then use as a sex attractant (Krasnoff and Dussourd, 1989) [66]. The nymphalid butterfly species *Ithomiine* and *Danaiine* exhibit comparable behavior. Plants containing PAs and sequester compounds, which function as precursors of hairpencil pheromones, are what attract and nourish *ithomiine* butterflies [67]. In addition to being engaged in sex recognition, hairpencil pheromones may possibly have other courtship functions. Certain mature *Danaiine* butterflies feed on alkaloids-containing plants, which they use as biological forerunners of the pheromones employed in courtship, which are used to dust females as they get closer [2].

Certain species of *Euglossine* bees are known to acquire or accumulate compounds from plants and use them for sexual purposes [68]. In reaction to sex pheromones, several beetle species, especially scolytids, form eating and mating aggregations on host plants [69]. Numerous examples could entail the acquisition of plant compounds and their usage as

pheromones or pheromone precursors, given the frequently high correlation that exists between feeding and sex attraction. Nevertheless, few studies have tried to understand the complex odor that is produced by the mix of host molecules, plant damage from eating at the site, and sexual communication. Plant chemicals, insect damage to the plant, microbes, frass, or insect de novo pheromone synthesis can all mediate or modify insect activity at such sites. At these feeding and mating areas, beetle sex pheromones may originate from plants due to one of three processes: (a) adult feeding on plant tissue, which results in chemical passage through the gut and release in the frass; (b) gut production from precursors received from plants; or (c) microbial action on plant material in the gut. Grain beetles with demonstrated sexual attractiveness and food dependence include *Sitophilus oryzae* [70], *Tribolium castaneum*, and *Rhyzopertha dominica* [71]. In this species, pheromone is only released when males eat grain; when food is taken away, no pheromone is released. In pitfall traps, male *Metamasius hemipterus* weevils were also unsightly unless they were accompanied by host plant material. However, the mechanisms underlying attraction variations in this and other species have yet to be experimentally proved [2].

Certain scolytid bark beetle species have been shown to create terpenoid pheromones derived from host tree terpenes. Landolt and Phillips [2]. Xu et al. [72] studied the effect of age, feeding, mating behavior on pheromone production in female asian longhorn beetle (ALB). Study revealed that  $\alpha$ -longipinene was the most dominant compound in the volatiles emitted by females. Virgin females produced more  $\alpha$ -longipinene than the mated females and unfed females never produced  $\alpha$ -longipinene at any age, whereas, in case of fed female, they produced more amount of  $\alpha$ -longipinene at the age 15-19 days old. Hence it shows that it was acquired only during adult feeding only. In case of field studies, they found that ALB volatile alone when applied solely in the field, their attraction is very less, but their attraction was synergistically enhanced when combined with the host volatiles or some sesquiterpenes. It implies a potentially important role of host plants both in inter and intra species chemical communication by ALB [72].

## 7. CONCLUSIONS

Chemical communication, the most important criterion between insects and their host plants,



cleared the path for improved pest management tactics. Pheromonal lures based on attract and kill have become more essential in insect pest management because they interrupt the mating and reproduction of their offspring. Many phytophagous insects from the coleoptera, lepidoptera, and dipteran families rely more heavily on host plant chemicals for chemical communication. In insect pest management, the combined action of pheromones and host plant volatiles has been shown to be significantly superior to the effect of either alone. As a result, this unique strategy may boost crop output by minimizing damage caused by insect pests, thereby preserving food and nutritional security.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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