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Infochemical Pattern for True Bugs

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Abstract: The true bugs are one of the most economically important insect pests in agro ecosystems. Several different pheromones for true bugs have been reported, including sex, attractant, aggregation and alarm pheromones. The term sex pheromone refers to a compound liberated by a female, with the dual purpose of both attracting the male from a distance. Sex pheromone of the hemiptera are largely produced by males. The sex attractant pheromones are typically volatile chemicals produced by either male or female members of species for successful courtship and mating. The aggregations pheromones are produced by either one or both sexes and serve to attract other individuals for feeding, mating and protection. Moreover, the alarm pheromones warn members of a species of impending danger and those are commonly easily disturbed and readily emit their offensive odor. In conclusion, important pheromones of the true bugs can be classified four different categories; sex, attractant, aggregation and alarm pheromones. The knowing them can be important key to monitor time of emergence of pest population, pest density, detection new pest species, decision of successful control program and using them as bait with insecitide trial.

Key words: True bugs, infochemical pattern

INTRODUCTION

The true bugs are the most common insects that occur in both terrestrial and aquatic habitats (Pedigo, 1996). The true bugs have approximately 80,000 species in the world (Gillott, 1995). Although many of them are important plant pests, many of them also are important natural enemies that help to destroy insect pests (Pedigo, 1996). The true bugs, like some of the other orders, have infochemical communication. Infochemicals are chemicals that convey interactions between organisms (Vet, 1999). They are divided into pheromones and allelochmicals (Noldus, 1989). Pheromones are emitted and received by members of the same species. Allelochmicals, divided into kairomones and allomones, emitted and received by members of different species (Noldus, 1989).

Several different pheromones for the true bugs have been reported including sex, attractant, aggregation and alarm pheromones. Sex pheromone have traditionally been considered by researches to be those compounds that are emitted by individuals of one sex to attract of members of the opposite sex, resulting in the location of the emitter and subsequently mating (Baker, 1989). The sex attractant pheromones are typically volatile chemicals produced by either male or female members of species (Gillott, 1995). The release and detection by the partner are essential prerequisites to successful courtship and mating. The aggregations pheromones are produced by either one or both sexes and serve to attract other individuals for feeding, mating and protection. The alarm pheromones warn members of a species of impending danger (Gillott, 1995).

The purpose of the review was to know infochemical pattern can be important key to monitor time of emergence of pest population, pest density, detection new pest species, decision of successful control program and using them as bait with insecitide trial.

RESULTS AND DISCUSSION

Sex Pheromones in Hemipterans

Sex pheromones are emitted by individuals of one sex in order to attract members of the opposite sex, resulting in the location of the emitter and subsequently, mating (Baker, 1989). Sex pheromones have been chemically identified for plant bugs (Miridae), assassin bug (Reduviidae), stink bugs (Pentatomidae) and shield bugs (Scutelleridae) (Aldrich, 1996). The pheromone chemistry of hemiptera is diverse, reflecting the extent of radiation of the group. Most hemipteran sex pheromones have been exploited by parasitoids as host-finding kairomones (Aldrich, 1996).

The female producing sex pheromone occurs in several mirid species that include the mullein bug, *Campylomma verbasci* (M.) (McBrien *et al*., 1999). The mullein bug is a serious pest on apples in several fruit growing areas of North America. The metathoracic gland might be source of the pheromone because pheromone extracts from the female head and thorax have been found to be the most attractive to males (McBrien *et al*., 1999). The sex pheromone of *C. verbasci* has been identified as a 16:1 blend of butyl butyrate and 2 (E)-crotyl butyrate (Smith *et al*., 1994; McBrien *et al*., 1996). Identification of a sex pheromone for *C. verbasci* has provided an opportunity for developing pheromone-based management programs for this pest (McBrien *et al*., 1996). In addition, suppression of overwintering populations of *C. verbasci* by atmospheric permeation with synthetic sex pheromone, 16:1 butyl butyrate: 2(E)-crotyl butylrate was accomplished. Atmospheric permeation with synthetic sex pheromone causes a reduction in the population density of a heteropteran (McBrien *et al*., 1997).

Some of the Hemipteran males also produce sex pheremone. The male-released semiochemicals of the stinkbug, *Piezodorus hybneri*, elicit attraction of male and female bugs and homosexual behavior in males (Leal *et al*., 1998). Three active components were isolated from the airborne volatiles of males by flash chromatography, with the activity monitored by GC-EAD and behavioral bioassays. The pheromone system was characterized as a mixture of β-sesquiphellandrene, (R)-15-hexadecanolide and methyl 8-(Z)-hexadecenoate (ratio: 10:4:1) and the activity of the semiochemicals was assessed with authentic samples. The behavioral observation and the fact that an onset of pheromone production is coincident with ovarian development strongly suggest that these semiochemicals are sex pheromones (Leal *et al*., 1998). Millar (1997) mentioned that the semiochemistry of the stink bug, *Thyanta pallidovirens*, headspace sampling revealed that sexually mature males produce a group of sex -specific compounds, including the sesquiterpenes zingiberene, curcumene and sesquiphellandrene. Moreover, Males of the bean bug *Riptortus clavatus* release semiochemicals that attract both males and females (Leal *et al*., 1995). On the other hand, 2-(E)-octenyl acetate + octanol are produced by both male and female of *Leptocorisa chinensis* and attract only males of the same species. The field experiment also showed that a 5:1 mixture of 2-(E)-octenyl acetate + octanol was very attractive for males of rice bug (Leal *et al*., 1996).

Attractant Pheromones in Hemipterans

The sex attractant pheromones are typically volatile chemicals produced by either male or female members of species, whose release and detection by the partner are essential prerequisites to successful courtship and mating (Gillott, 1995). The attraction of males to females has been demonstrated for a number of hemipteran species; several lygus bug species, the cocoa capsid bug, *Distantiella theobroma* (Dist.), the cocoa mirid, *Helopeltis clavifer* (Walker), the green apple bug, *Lygocoris communis* (Knight), the apple brown bug, *Atractotomus mali* (Meyer), the green capsid bug, *L. pabulinus* (L.), the tea mosquito bug, *Helopeltis antonii* (Sign.), *Calocoris norvegicus* (Gmelin), *Neurocolpus longirostris* Knight and the rice leaf bug, *Trigonotylus caelestialium* (Kirkaldy) (McBrien *et al*., 1999).

The sex attractant pheromone produced by adult females of the mirid bug *Phytocoris californicus* has been identified as a 2:1 blend of hexyl acetate and E2-octenyl acetate (Millar and Rice, 1998). The pheromone is stage-sex and species-specific, attracting only adult male *P. californicus*. Hexyl acetate was identified in aeration extracts from both sexes, whereas only females produced E2-octenyl acetate. Both males and females also produced hexyl butyrate and hexanol, whereas only females produced octyl acetate, E2-hexenyl and octenyl acetates, Z3-octenyl acetate and E2-octenyl butyrate (Millar and Rice, 1998). Moreover, the sex attractant pheromone produced by adult females of the mirid bug, *P. relativus*, has been identified as a 2:1 blend of hexyl acetate with (E)-2-octenyl butyrate. The pheromone is stage-sex and species–specific, attracting only adult male *P. relativus*. Hexyl acetate was identified in aeration extracts from both sexes, while (E)-2-hexenyl and octenyl acetates and (Z)-3-octenyl acetate (Millar *et al*., 1997). The spined citrus bug, *Biprorulus bibax* Breddin, females released in the flight cage demonstrated significantly greater attraction to pheromone baited sites than unbaited sites (James *et al*., 1994a). Postdiapause, prereproductive females were more attracted to baited synthetic blend sites that of unbaited sites. Almost twice as many bugs were recorded from dorsal abdominal gland baited sites than unbaited sites. Synthetic blend-baited sites attracted 1.6 times as many bugs as dorsal abdominal gland baited sites. The females also responded significantly to sites baited with the hemiacetal major component alone (1.7-2.2 times more than unbaited sites) (James *et al*., 1994b). Moreover, pheromone produced in the enlarged males dorsal abdominal gland of the predaceous pentatomid, *Podisus maculiventris*, serves as a long-range attractant for conspecifics (Aldrich *et al*., 1984) and a synthetic version is now available commercially. The pheromone produced by male *B. bibax* may have a similar function and a synthetic version could have potential as a monitoring or management tool for this pest (James *et al*., 1994a, b). The blend of (E)-2,7-octadienyl acetate and (E)-2-ocetate (1:10 by volume) was identified as a pheromone attractive to both sexes of the lygaeid bug, *Tropidothorax cruciger*. These constitute the pheromone of *T. cruciger*, which is produced in the paired tubular glands attached to the main reservoir of the metathoracic scent gland complex (Aldrich *et al*., 1997). In addition, in a parallel investigation of *Neacoryphus bicrucis* (Lygaeidae), (E, E)-2, 4-hexadienyl acetate and phenethyl acetate were identified from males and found to be attractive to both sexes of adults in the field. The pheromone was clearly shown to come from the tubular accessory glands of the metathoracic scent gland (Aldrich *et al*., 1997). In another lygaeid, *Oncopeltus fasciatus*, 2-isobutyl-3-methoxypyrazine was identified in the cardiac glycoside-laden fluid sequestered from milkweed hosts and expelled by these bugs when they are attacked. Alkyl methoxypyrazines are warning odorants associated with poisonous insect secretions and their presence in *O. fasciatus* indicates that the plant-derived chemical defense of lygaeines is more elaborate than previously appreciated (Aldrich *et al*., 1997).

The hemipterans of the coreid and alydid males emit volatile blends that are probably an attractant pheromone (Aldrich *et al*., 1993). Aeration and exocrine gland extracts were analyzed for three Coreidae and two Alydidae. In the coreids, *Amblypelta lutescens lutescens*, *Amblypelta nitida* and *Leptoglossus phyllopus*, the metathoracic scent glands are not sexually dimorphic, but male and species-specific volatiles are released, apparently from cells in the cuticular epidermis. The coreid male-specific volatiles are primarily monoterpenes and sesquiterpenes. In the alydids, *Riptortus serripes* and *Mirperus scutellaris*, the metathoracic scent glands are sexually dimorphic and the dimorphisms are expressed chemically. Secretions from the male alydids contain high concentrations of ester or alcohol ((E)-2-hexenyl (Z)-3-hexenoate, (E)-2-hexenyl butyrate and (E)-2-octenol), while females produce mainly acids and aldehydes (butyric and hexanoic acids and (E)-2-hexenal) (Aldrich *et al*., 1993).

The Nearctic stink bug males, *Euschistus obscurus*, release an attractant pheromone (Borges and Aldrich, 1994). Methyl (2E, 4Z)-decadienoate and Methyl 2, 6, 10-trimethyltridecanoate are described as attractant pheromone for *Euschistus* sp. (Aldrich *et al*., 1994). Males of the *Euschistus obscurus* produce methyl (2E, 4Z)-decadienoate (61%) in abundance, which is characteristic of North America species and Methyl 2,6,10-trimethyltridecanoate (27%), the main male -specific ester of *E. heros* (Aldrich *et al*., 1994).

An Australasian predaceous bug, *Oechalia schellendbergii,* adult males have dorsal abdominal glands that are much larger than those of females and these glands are homologous to those of other predatory bugs whose male-specific secretions have proven to be attractant pheromones (Aldrich *et al*., 1996). Moreover, males of the spined soldier bug, *P. maculiventris*, have an enlarged dorsal abdominal gland from which they release an attractant pheromone consisting of a mixture of (E)-2-hexenal, α-terpineol, linalool, terpinen-4-ol and benzyl alcohol. Both sexes are attracted to natural or synthetic versions of this volatile blend and at least four parasitoids use the pheromone as a kairomone (Aldrich *et al*., 1984). Males of the generalist predators, *Podisus maculiventris* Say, attract mates with a pheromone but the immature stages of the predator also appeared to be attracted. *Podisus maculiventris* nymphs were significantly attracted to synthetic pheromone both in the laboratory and in the field. The discovery that the immature stages of *Podisus maculiventris* are apparently attracted to synthetic pheromone and are stimulated to search for and to feed on prey when exposed to pheromone, open new avenues for manipulation of these beneficial insects. (Sant'ana *et al*., 1997). As a result, it may be practical to harvest wild adults in pheromone -baited traps to mass-produced young predators for augmentative biological control (Aldrich, 1998).

The parasitic Scelionidae (Hymenoptera) and Tachinidae (Diptera) use these secretions as a kairomone. The fact that dorsal abdominal gland extract from *N. viridula* females elicits acceptance by *Trissolcus basalis* is added evidence that parasitoids use dorsal abdominal gland odors as kairomones (Aldrich *et al*., 1995). The capability to catch hundreds of a generalist tachinid fly parasitoid, *Euclytia flava*, alive in traps baited with the pheromone of *P. maculiventris* provided an opportunity to test the premise of the new associations biological concept (Aldrich, 1995). The tachinid parasitoids of *Acrosternum* and *Eurydema* species seem to prefer to oviposit underneath the wings of their host. Over 90% of the tachinid egg on *Brochymena* sp. (Pentatomidae) area hidden underneath the wings (Aldrich *et al*., 1995). Alternative explanations for this type of oviposition are that the flies can not stick their eggs to the powdery wax on *Brochymena* adults (Aldrich, 1988) or that concealing eggs protects them from adverse environmental conditions (Eger, 1981).

Aggregation Pheromones in Hemipterans

The aggregations pheromones are produced by either one or both sexes and serve to attract other individuals for feeding, mating and protection (Gillott, 1995). Many true bugs have been known to use both sex and aggregation pheromones. Species of the hemipteran use an aggregation pheromones including *Oncopeltus fasciatus* D., *E. rugosa* M., *P. maculiventris* S., *N. viridula* L., *L. australis* F., *L. occidentalis* H. and *Pristhesancus plagipennis* (James *et al*., 1994b; Blatt and Borden, 1996). In addition, observations of field studies have indicated that the false chinch bug or radish bug, *Nysius raphanus* Howard produces aggregation pheromone (Demirel and Cranshaw, 2006a-d). Overwintering aggregation is very common in the hemipteran; western conifer seed bug, *L. occidentalis* H., *L. corculus* S., Boxelder bugs, *Boisea rubrolineata* B., Swallow bugs, *Oeciacus vicarius* H., chinch bugs, *Blissus leucopterus* S. (Blatt, 1994).

The males for two coreid and reduviid species produce aggregation pheromone. Male *Leptoglossus australis* attracted conspecific adults of both sexes and nymphs (Yasuda and Tsurumachi, 1995), whereas male western conifer seed bugs, *L. occidentalis*, produced an aggregation pheromone in autumn, which attracted adults of both, sexes (Blatt and Borden, 1996). A male assassin bug, *Pristhesancus plagipennis* produce aggregation pheromone. The calling males release a pleasantsmelling odor from these glands comprised largely (ca. 60%) of a novel ester, (Z)-3-hexenyl (R)-2-hydroxy-3-methylbutyrate, with 3-methylbutanol, 2-phenyl-esters, as minor components. The major ester alone was attractive to female *P. plagipennis* in olfactometer and flight-cage tests. The major ester was also attractive to males, indicating that the compound functions as an aggregation pheromone (James *et al*., 1994b). Furthermore, an effective, synthetic aggregation pheromone for *P. plagipennis* would be of considerable value to more effective and widespread utilization of this predator in managing populations of the citrus bug pest *Biprorulus bibax*. Pheromone could be used to concentrate *P. plagipennis* populations in citrus orchards to enhance biological control (James *et al*., 1994b).

Alarm Pheromones in Hemipterans

Alarm pheromones warn members of a species of impending danger (Gillott, 1995). Most insect alarm pheromones are produced and delivered from the mandibular or anal gland or from the sting apparatus (Harborne, 1988). These members of a species share the following common characteristics: easily disturbed and readily emit their offensive odor, form aggregations and most possess hexanal as a component of their defensive secretion (Blatt *et al*., 1998). The coreids, *L. zonatus* (Dallas), *Hotea gambiae* (Westwood) and *L. occidentalis*, the alydids, *Megalotomus quinquespinosus* (Say), *Alydus eurinus* (Say) and *A. pilosulus* Herrich-Schaeffer, the pentatomids, *Dysdercus intermedius* Distant, *E. rugosa* Motschulsky and *E. pulchra* Motschulsky, *N. viridula* L. and *Erthesina fullo* Thungbers, the bedbug, *Cimex lectularius* L., a pyrrhocorid have been characterized as eliciting alarm behaviors among conspecifics (Blatt *et al*., 1998). Moreover, the false chinch bugs, *N. raphanus* Howard, might have alarm pheromones as well. The false chinch bugs are easily disturbed and release an odor when touched them (Demirel, 2003).

Hexaldehydes are common components in hemipteran alarm pheromone and defensive secretions, having been found in the *Coreidae*, *Pentatomidae*, *Pyrrhocoridae*, *Cimicidae*, *Cydnidae* and *Alydidae* (Lockwood and Story, 1987). The alarm pheromone system of *L. zonatus* (Dallas) adults was shown to be composed of hexyl acetate, hexanol, hexanal and hexanoic acid. Single components tested in the field elicited dispersal behavior of over 70% of adults. 2-(E)-hexenal, found in secretions of nymphs, was also active to adults.

Adults and nymphs possess different alarm pheromone systems, which are not specific to their own life stage (Leal *et al*., 1994). The defensive secretion of the southern green stink bug, *N. viridula* was found to function as an alarm pheromone by including an orthokinetic, nontactic response. The single components, E-2-hexenal and E-2-hexenyl acetate, significantly increased movement during the first minute of exposure at doses of 0.1 and 1.0 µL In addition, (E)-2 -hexenal has effect as an alarm pheromone on both nymphs and adult of *D. intermedius* (Distant) (Lockwood and Story, 1987).

The western conifer seed bug, *L. occidentalis* Heidemann, is a common and potentially severe pest of conifer seed orchards in western North America (Connelly and Schowalter, 1991). The utilization of different pheromone compounds by adults and nymphs of *L. occidentalis* may indicate that pheromones with different properties are required to accommodate their different release mechanisms. Adult *L. occidentalis* expel their pheromone through small openings in the thorax as a spray while nymphs release alarm pheromone through openings in their abdominal tergites. Hexanal, produced by adults, has a higher molecular weight than (E)-2-hexenal and is less volatile. Hexanal may disperse into the air as an aerosol or may contact a predator prior to volatilization (Blatt *et al*., 1998). The (E)-2-hexenal, if release in a similar manner, will colatilize rapidly on exposure to air. As (E)-2-hexenal is probably released onto the surface of the tergites, rather than directly into the air, the large odor plume created would probably be as effective as a hexanal spray in warning off predators, particularly from a group of aggregated and alarmed nymphs (Blatt *et al*., 1998).

The pentomid bug, *Erthesina fullo* Thunberg, is a major pest of pine trees and hardwood tree in Taiwan (Kou *et al*., 1989). The odor from the male metathoracic scent gland elicits an alarm response, making the male individuals of the same species alert and dispersive. The alarm response of males is more obvious than that of the females. Chemical composition of the glandular secretion was identified by gas chromatography and mass spectrometry. A total of nine compounds; (E)-2-hexenal, (E)-4-keto-2-hexenal, (E)-2-hexenyl acetate, n-undecane, n-dodecane, (E)-2-decanal, n-tridecane, (E)-2-decenyl acetate and n-pentadecane, were identified, among which n-tridecane and (E)-4-keto-2-hexenal comprised nearly 70% of the total secretion in both females and males (Kou *et al*., 1989).

The hawthorn lace bug, *Coryhucha cydoniae* and the eggplant lace bug, *Gargaphia solani*, possess alarm pheromones that are produced in dorsal abdominal glands (Aldrich *et al*., 1991). When the *G. solani* nymphs are grasped, they emit secretion from both dorsal abdominal glands; the posterior dorsal abdominal gland secretion alone elicits alarm, but the anterior dorsal abdominal gland secretion may hasten the response (Aldrich *et al*., 1991). In *Coryhucha cydoniae*, the response is due to a synergism between the anterior and posterior dorsal abdominal gland secretions and nymphs are apparently unable to voluntarily release their dorsal abdominal gland secretions; both dorsal abdominal glands must be ruptured for the pheromone to escape. The alarm pheromones are interspecifically active in patterns matching the intraspecific activities. Compounds identified from tingid dorsal abdominal gland secretions that involve in the alarm messages are (E)-2-hexenal, (E)-4-oxo-2-hexenal, acetaldehyde, geraniol and linalool (Aldrich *et al*., 1991).

In conclusion, the true bugs are not only important plant pests but also important predator of many plant pests. A significant number of the pheromones of the true bugs have been classified in four different categories; sex, attractant, aggregation and alarm pheromones. The knowing them could be an important key to monitor time of emergence of pest populations, pest density, detections new pest species, decisions for a successful control program.

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