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INSECT COMMUNICATION: HIDDEN MESSAGES BEHIND SURVIVAL

A. Shobha Rani[1], T. Siva Kumar[2], E. Bhuvaneswari[3], M. Divyabharathi[1] and G. Savithri[1]*
[1]Department of Biosciences and Sericulture, Sri Padmavati Mahila Visvavidyalayam (Women's University), Tirupati-517 502, Andhra Pradesh, India
[2]AP Model School and Jr. College, Settur, Anantapur, Andhra Pradesh, India
[3]Scientist-D, Research Extension Centre, Chebrolu, Central Silk Board, Ministry of Textiles, Chebrolu-533449, Andhra Pradesh

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***Corresponding author**
G. Savithri

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Abstract
The earliest evidence of life on Earth dates back 480 million years, according to palaeontologists. Life evolved from microscopic cellular forms to complex multicellular organisms. Throughout evolutionary history, the advancement of life as a group would not have been possible without cells, tissues, and systems communicating with each other through specific communication mechanisms. It is interesting to study the mechanisms of communication associated with insects and the use of various signals to convey different kinds of information. Insects have a wide range of mechanisms, including acoustic, visual, chemical, and tactile communication. More important is the evolution of animals' use of signals to share information about predators.

Keywords: *Insects, facial expressions, communication, sex pheromones and posture.*

INTRODUCTION

The Latin term communications, which means to share or create a shared understanding, is where the word communication originated [1]. It may be referred to as the process of recognising and expressing a shared meaning [2]. It is the sharing of information between two people: the emitter, who sends the message, and the receiver, who receives and interprets it. Most of the insect language is inherited and inherent. Every person has a unique vocabulary from birth that they only share with other members of their own species. It is a crucial component of every social exchange.

An action or circumstance on the part of one organism that modifies the behaviour of another organism in an adapted way is commonly defined by ethnologists as communication. Insects use touch, smell, sound, and sight to communicate. They communicate primarily with other members of their own species. They employ a variety of signals to attract prey or deter predators, find partners, warn of danger, and provide information about food supplies. Insects communicate using chemical, tactile, acoustic, and visual means, in contrast to humans who use nonverbal cues such gestures, posture, facial expressions, eye contact, distance between two people, and spoken language. To communicate a single idea, a combination of different methods may occasionally be employed. Honey bees and other social insects use complex mechanisms including language, facial recognition, symbolic communication, number use, mimicry and observation, comprehension of rules, and sophisticated problem-solving [3].

Scientists have been fascinated by social insect communication for many generations. The honeybee dancing language is among the most well-known examples. Since Von Frisch's 1967 [4]discovery which earned him the Nobel Prize in 1973-that honeybees use dance to communicate with their nest-mates about the availability of resources, our understanding of the topic and social insect communication techniques has significantly changed for a variety of species.

What Is The Purpose Of Insect Communication?

1. Identification of nest mates or colony members

2. Finding or recognising an individual of the opposite sex
3. Assistance of courting and mating
4. Directing the placement of food
5. Controlling the geographical distribution of individuals, aggregation or dispersal; creating and upholding a territory
6. Transmission of alarm signals in response to threats
7. Threatening or submitting and Imitating.

How Can Insects Able To Communicate?

Insects use their five senses to learn about their surroundings, just like all other creatures do. Information can be exchanged by any of these sensory modalities. Since taste and touch are contact senses, information can only be shared when two people are near one another. Remote senses and information signals that can travel great distances through the air (or water) include vision, smell, and hearing. Therefore, an insect could do something to send a communication signal. The signal might just be a natural aspect of the insect's physical characteristics, such as its surface chemistry, body colour, or wing pattern. In either scenario, for a human observer to detect the signal, it must cause a behavioural shift.

Types of Communication in Insects

One might use such cues as insects' language. Individual traits that an emitter transmits and that a receiver uses to decipher information about the emitter are known as cues. On the other hand, a sender's information may also be exploited by a second recipient to the sender's detriment (e.g., by parasites to find hosts) or used to trick the recipient to the sender's detriment (e.g., predators luring prey by imitating prey signals)[3,5]. Insects use different mode of communication, including chemical, tactile, auditory, and visual ones, to communicate both within and across species.

1. Acoustic communication

Insects employ acoustic communication as a vital mechanism for mating, territorial defense, and social coordination, using species-specific sounds to navigate complex environments. These signals, ranging from low-frequency vibrations to high-pitched chirps, evolved independently across orders like Orthoptera (crickets, grasshoppers) and Diptera (mosquitoes), showcasing remarkable diversity in production and reception.

Insects generate sounds through stridulation, where body parts rub together wings against legs in crickets or file-like structures on katydids producing pulses up to 100 kHz. Wing vibration creates flight tones in mosquitoes (300-800 Hz), while percussion (tapping substrates) and air expulsion occur in cicadas and termites. Tremulation, bodily shaking, transmits vibrations through plants for tree hoppers and ants.

Sounds reach insects via tympanal ears on abdomens (moths, grasshoppers), forelegs (crickets), or antennae with Johnston's organ (mosquitoes, Drosophila). Subgenual organs in legs detect substrate vibrations, enabling communication over distances without airborne loss. Neural processing in auditory neurons encodes pulse rates and harmonics with vertebrate-like precision [6].

Males of field crickets (*Gryllus* spp.) sing calling songs to attract females, rival songs to repel intruders, and courtship songs post-attraction. Mosquitoes (*Aedes aegypti*) synchronize wingbeats at harmonics (e.g., 1,400 Hz) for mate recognition, avoiding same-sex jamming. Sandflies (*Lutzomyia longipalpis*) use pulse/burst songs for cryptic speciation; triatomines (*Triatoma infestans*) stridulate to deter rivals.

Acoustic signals drive sexual selection, speciation, and predation risks parasitic flies home in on cricket songs to oviposit. Dating back 300 million years, these systems persist amid noise pollution challenges, informing biocontrol strategies.

2. Visual communication

Visual cues are used in visual communication to convey information. It has the same benefit as acoustic in that it allows for precise sender location during courtship. The main drawback is that it isn't practical over long distances. There are few visual cues used in inter-individual communication among social insects. However, under other circumstances, such as when foraging stingless bees are tracking the leader visually, a well-developed vision may be helpful. When it comes to nocturnal insects and underground insects like termites, it is not very helpful. Insects use visual communication to detect possible partners, prey, predators, and food sources [3, 6].

3. Chemical communication

It is widely accepted that chemical mechanisms dominate insect communication. It is the initial kind of communication in insects [7]. Chemical communication has an advantage over other forms of communication since it does not require physical contact between the sender and the recipient via a medium or substrate. Even if the insects are far apart, communication is still possible. Semi chemicals are substances that transfer information between two organisms. According to Dethier[8], These substances follow pathways that enable them to perform six major roles. 1. locomotor stimulants; 2. attractants; 3. arrestants; 4. repellents; 5. feeding and ovipositional stimulants; and 6. deterrents. Semi chemicals are divided into two subcategories namely (i) allelochemicals and (ii) pheromones.

Allelochemicals: These are secondary metabolites produced by plants that mediate interactions with insects, acting as natural chemical defenses in a coevolutionary arms race. These non-nutritive compounds influence insect behavior, physiology, growth, and reproduction, often deterring herbivores or manipulating host selection.

In plant-insect dynamics, allelochemicals function as allomones (benefiting the plant, like repellents) or kairomones (benefiting the insect, like attractants for oviposition). Categories include antifeedants, toxins, enzyme inhibitors, and pheromonal cues; examples alkaloids (nicotine), phenolics (tannins), terpenoids, and glucosinolates. Glucosinolates from crucifers, for instance, break down into isothiocyanates that repel generalists but attract specialists like Hellulaundalis moths for egg-laying.

Allelochemicals target insect digestion by inhibiting proteases (trypsin, chymotrypsin) via Kunitz or Bowman-Birk proteins, or amylases with α-amylase inhibitors from beans, starving larvae like Manduca sexta. Neurotoxins such as nicotine bind acetylcholine receptors, causing paralysis, while neem's azadirachtin disrupts ecdysone, halting molting in Helicoverpa pests. Repellents like eugenol in clove oil activate olfactory receptors, driving insects away [3].

Pheromones

A pheromone is a chemical substance released into the environment by an organism that elicits a specific response in another individual of the same species. Pheromones are usually secreted as liquids from the exocrine glands, where these substances volatilize into the surrounding air, creating a cloud of vapor that envelops the signaling organism [9]. The volatility of the molecule, its stability in the air, its rate of diffusion, the olfactory efficiency of the receiver, and, of course, wind currents [10].

Pheromones can affect the central nervous system in two different ways. One family of compounds causes an instantaneous behavioural response upon receipt, much like releaser pheromones. Conversely, primer pheromones have a delayed impact on behaviour. In social insects, primer pheromones have an inhibitory effect on population growth [11]. In desert locusts, for example, the primer pheromone released by adult females accelerates the growth of both male and female nymphs to achieve synchronous growth within the species. The types of releaser pheromones are as follows:

a. Sex Pheromones

Sex pheromones are the substances released to signal reproductive readiness among conspecifics to promote mating, or carry out other tasks intimately associated with sexual reproduction. In particular, sex pheromones are used to identify females for breeding, attract the opposite sex, and transmit genotype, species, age, and sex information. Since non-volatile pheromones, also known as cuticular contact pheromones, are typically detected by direct touch with chemoreceptors on an insect's antennae or feet, they are more closely associated with social insects. In research, sex pheromones of insects are utilized to track and control problematic species[3,6].

b. Alarm pheromone

Insect alarm pheromones, which are often composed of terpenoids, ketones, or aldehydes and act as quick, short-range warnings from glands near the sting or mandibles, are volatile chemical signals released in response to threats that cause defensive behaviours like dispersal (aphids dropping from plants) or aggression/recruitment (bees/ants attacking) in other colony members. They can draw predators, starting an evolutionary "arms race," yet they are essential for social insects to swiftly deploy defence.

c. Aggregation pheromone

It is a Chemicals emitted to gather members of species.Insects, such as bark beetles, thrips, and fruit flies, aggregation pheromones are chemical signals that draw both sexes of the same species to congregate for survival, reproduction, or feeding. They essentially function as "party pheromones" to form groups, frequently near food, and are essential for managing pests and comprehending insect behaviour. One sex typically males releases these semiochemicals, which direct other sexes to an advantageous area, increasing the likelihood of mating and facilitating effective resource exploitation. Some of these compounds exhibit flexibility depending on food or density [3,6].

d. Trail Pheromones

Pheromones that direct insects along established trails to lead colony members. Insects that are social, such as termites, ants, and bees, use chemical signals called trail pheromones, which are frequently volatile hydrocarbons, to create scent trails that direct nestmates to food, water, or new nest locations. These trails are short-lived and occasionally contain repellents to maximize colony movement.

e. Epideictic Pheromones :

Epideictic pheromones are chemical cues that are frequently released in the vicinity of egg-laying locations to alert other females of the same species to stay away, avoiding congestion and resource rivalry. These pheromones, such as those produced by fruit flies or parasitic wasps, indicate that a host or substrate has already been utilised, improving resource allocation and spacing for progeny. They differ from trail or sex pheromones in that they are a kind of marking pheromone that encourages spacing out [3,6].

f. Territorial Pheromones

Territorial pheromones are chemical signals, usually hydrocarbons or alcohols that are released to mark and defend space, deter rivals, attract mates to a particular area, and organise social groups. Ants use them to mark boundaries for foraging, butterflies use them to deter rival males, and cockroaches use them for aggregation. These signals are detected by specialised receptors on antennae for quick communication within the same species [3,6].

Applications of insect Pheromones

Leveraging their species-specificity to reduce environmental effect, insect pheromones are mostly used in integrated pest management (IPM) for agriculture. Monitoring and Detection: Early detection of low-density pest infestations by pheromone-baited traps allows for prompt intervention. For example, cotton pink bollworm (Pectinophoragossypiella) traps reduce the need for broad-spectrum treatments by signalling infection thresholds.

Mating Disturbance

Synthetic sex pheromones are sprayed on fields by aerial or ground distributors, confounding men and obstructing their ability to find mates. This reduces larval damage by 50–90% with no residues, controlling both grape berry moths and codling moths in apple orchards.

Mass trapping and lure-and-kill

Traps inhibit reproduction by capturing males (such as fruit flies and stored-product beetles like Tribolium castaneum). "Lure-and-kill" mixes insecticides and pheromones to specifically eradicate pests such as cotton bollworms.

Aggregation pheromones manage bark beetles by luring them to traps, while alarm pheromones enhance biocontrol. These eco-friendly tools support organic farming, resistance management, and yield protection across crops like maize, groundnuts, and stone fruits [3,6].

4. Tactile Communication

Information is transferred by physical contact between people in tactile communication. It is a short-range method of communication that doesn't require the two insects to be close to one another or an external media to convey information. Insects use their legs to tap and contact antennae to transmit tactile signals. Although they are typically limited to interactions between two or a few people, tactile exchanges can be an essential part of communication. One common form of tactile communication between nestmates is antennation and grooming. Insects that inhabit dark underground environments, such as termites, have highly developed tactile communication despite having underdeveloped eyes. Trophallaxis, which makes use of antennae and forelegs to exchange food, is a prime example of tactile communication [3,6].

Conclusion

All of the four forms of insect communication has pros and cons of its own. Significant technical developments in recent decades have greatly enhanced our ability to capture, evaluate, and synthesize different types of information. Therefore, combining our knowledge from these many fields could lead to new and intriguing discoveries about insect communication in all of its unique aspects.

Integrating communication-based strategies, such as the use of pheromones and other signaling cues, enhances sustainable farming and sericulture practices by enabling targeted pest management and reducing the overuse of chemical pesticides. Understanding insect signaling pathways not only helps control harmful species but also contributes to the conservation of beneficial insects, which play essential roles in pollination and ecological balance. Overall, research on insect communication provides a foundation for developing effective, eco-friendly approaches that safeguard crop yields, maintain healthy sericulture systems, and promote long-term agricultural sustainability.

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