OPEN ACCESS

Haya: The Saudi Journal of Life Sciences
Abbreviated Key Title: Haya Saudi J Life Sci
ISSN 2415-623X (Print) | ISSN 2415-6221 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Review Article

A Review on Understanding the Plant's Secret Language for Communication and its Application

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DOI: 10.36348/sjls.2024.v09i01.001 | **Received:** 29.11.2023 | **Accepted:** 03.01.2024 | **Published:** 05.01.2024

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Abstract

Plants engage in communication through diverse methods, encompassing chemical signals, sound waves, and root networks. These signals serve to convey information about environmental challenges such as drought and disease, and play a role in attracting pollinators or deterring predators. Coined as the "plant's secret language" by Tompkins and Bird in 1973 [1] Tompkins, P., & Bird, C. [1973]. Scientists have identified specific compounds that plants use to signal to one another, including volatile organic compounds [VOCs] and herbivore-induced plant volatiles [HIPVs] that can be released into the air and root exudates that are released into the soil. Recent research has shed light on the mechanisms behind this communication, revealing that plants have a sophisticated network of sensory and signalling pathways that allow them to perceive and respond to various stimuli. The review covers a range of topics, including how plants communicate with each other, how they respond to biotic and abiotic stresses, and how they use this communication to defend against pathogens and predators[herbivore]. It also discusses the potential applications of this knowledge in various fields, such as agriculture, medicine, and environmental monitoring. Overall, this review study highlights the importance of understanding the plant's secret language for communication and its potential applications in various fields like agriculture, conservation, and medicine.

Keywords: Plant communication; secret language; VOC; applications.

INTRODUCTION

The secret language of plants refers to the complex and diverse ways in which plants communicate with each other and their environment. While plants lack a central nervous system, they have evolved a wide range of chemical and physical signalling mechanisms that allow them to respond to changes in their environment and interact with other plants and organisms [2]. Some plants release volatile organic compounds [VOCs] to warn neighbouring plants of danger. This signal causes the neighbouring plants to increase their production of defensive compounds, such as toxins and thorns. This helps to protect the plants from herbivores and other predators [3, 4]. Plants use a variety of chemical signals to communicate with each other, including root exudates. Root exudates are chemical compounds released by plant roots that can influence the growth and behaviour of other plants in the surrounding soil. Throughout different phases of their evolutionary progression, plants exhibit electrical signals reminiscent of neural impulses. An experiment dedicated to exploring this phenomenon was conducted utilizing potato [*Solanum tuberosum* L] plants. These electrochemical waves, akin to the action potentials found in more sophisticated plant species, have the potential to act as carriers for transmitting information during intercellular and intracellular communication. This becomes especially significant in the context of responding to environmental changes [5]. Understanding the secret language of plants has important implications for agriculture, forestry, and conservation. By studying how plants communicate with each other and respond to changes in their environment, researchers can develop new strategies for managing crops and forests, improving plant health, and protecting endangered species [6]. In recent years, advances in technology have allowed researchers to study plant communication in more detail, revealing new insights into the complex and sophisticated ways in which plants interact with their environment and each other [7]. When plants are subjected to physical stimulation during herbivory, the resulting vibrations can trigger defense responses in the plants. This was supported by an experiment where tobacco plants showed increased nicotine accumulation in response to recorded vibrational signals produced by potato tuber moth [*Phthorimaea operculella*] larval feeding [6]. It is possible that hair cell trichomes on the surfaces of stems and leaves serve as mechanosensory switches, priming the plants to respond to vibrations [7]. The continuous mechanical wounding/damage caused by a worm i.e., leaf-eating beetles [*Coleoptera]* or caterpillars [*Lepidoptera*]] was able to elicit JA-responsive [Jasmonates] defense responses in lima bean [*Phaseolus lunatus*], possibly due to the amplification of vibrations in the leaves [8]. However, unlike the damage caused by *Spodoptera littoralis*, neither a single instance of wounding nor continuous mechanical wounding in lima bean leaves induced plasma membrane depolarization or Ca^{2+} influx. This suggests that in some plant species, such as lima beans with poorly developed trichomes, continuous herbivory-induced damage is not linked to vibrational stimuli. Nevertheless, vibrations are likely to act as herbivory damage signals in plants with well-developed trichomes, as trichome stimulation may influence cytosolic Ca^{2+} oscillations and shifts in apoplastic pH [9, 10].

Plants emit organic chemicals into the air, which can have an impact on other living things. A research article explored how these chemicals can enable plants to communicate with each other and improve their protection against pests and diseases in a sustainable manner. It described how plants generate and sense various types of these chemicals, and how they affect plant reactions to herbivores and pathogens. It also demonstrated how these chemicals can assist plants to attract predators of pests, to warn nearby plants of threats, and to trigger systemic resistance against infections. Moreover, it discussed how these chemicals could be used as substitutes or additions to traditional pesticides, by altering plant signalling pathways or by applying artificial chemicals in the field [11]. Beck and co-authors also highlight the challenges that need to be addressed before VOC-based pest management strategies can be widely adopted, such as understanding the complex interactions between plants and their microbiome, as well as optimizing the use of VOCs in the field [12]. Recently, a multitude of investigations have advocated for the utilization of plant-derived volatile organic compounds [VOCs], encompassing both direct induced volatile emissions [DIVs] and herbivore-induced plant volatiles [HIPVs], to foster eco-friendly pest management strategies in agriculture. Thus potential of directly induced volatile emissions [DIVs] to initiate an enhanced release of volatile organic compounds [VOCs] in neighbouring plants could serve as an intriguing foundation for signal amplification in an agricultural landscape. Hypothetically, if controlled injury to a few plants could trigger an increase in VOCs in undamaged neighbouring plants, which in turn act as relays to magnify the signal, it becomes an interesting prospect to investigate whether this mechanism could effectively stimulate resistance across broader sections of a field. Nevertheless, the viability of this concept hinges on several factors, including the strength and frequency of the stimulus, the stability and intricacy of the signal, the capacity of recipient plants to perceive and react to the stimulus, the durability of the response, and whether there exists a trade-off between defense mechanisms and crop yield. It is pertinent to mention a recent study that sheds light on this matter – it revealed that among the released VOCs, particularly green leaf volatiles [GLVs], emerged as prime candidates for indicating the presence of herbivores. This suggests that GLVs might persist in the environment for a more extended period compared to other volatile compounds [13, 14].

The transmission of signals involving electrical impulses, calcium ions, and reactive oxygen species [ROS] is essential for systemic acquired acclimation and wound communication within the same plant's local and systemic tissues. However, whether these signals can traverse between distinct plants remains a largely uncharted territory. Report reveals a novel form of aboveground inter-plant communication that encompasses electrical signalling on leaf surfaces, ROS propagation, and interactions within photosystem networks. When a single dandelion leaf undergoes wounding or experiences high light stress, a foliar electrical signal emerges. This signal can travel to an adjacent plant that shares direct contact with the stimulated plant. This interaction yields systemic alterations in photosynthetic activity, oxidative responses, molecular processes, and physiological states in both the stimulated and neighbouring plants. This study also demonstrates the capacity of electrical signals to serve as a channel for communication between transmitting and receiving plants, particularly within a network or community of plants. This intricate mechanism can be characterized as network-acquired acclimation, indicating the acquisition of adaptive responses through interconnected signalling [15]. This goes on to describe recent studies that have shed light on the role of plant communication in different ecological contexts, such as plant-microbe interactions, plant-herbivore interactions, and plant-pollinator interactions. Also discusses the potential applications of plant communication research in agriculture, such as the development of new pest management strategies and the optimization of crop yields [16, 17].

Probable way of plant's secret language:

One example of the secret language of plants is the phenomenon of "talking trees," where trees can communicate with each other through underground networks of fungi [18]. Mycorrhizal fungi, a diverse range of fungal organisms, establish a mutualistic relationship with plant roots, forming a symbiotic interface known as mycorrhiza. This intricate association yields advantageous outcomes for both participants. The mycorrhizal fungi take residence within plant roots, instigating the growth of hyphae—thin, thread-like structures. These hyphae extend into the adjacent soil, vastly amplifying the region primed for nutrient and water absorption. This, in turn, significantly enhances the plant's capacity to assimilate vital elements such as nitrogen, phosphorus, and micronutrients. Concurrently, the mycorrhizal fungi derive benefits from this alliance by receiving sugars and other organic compounds from the plant. As these fungi are incapable of photosynthesizing independently, they rely on the plant to furnish them with essential nutrients. Through the conduit of the root system, the carbohydrates produced by the plant's photosynthesis are channelled to the fungi, ensuring their sustenance and growth [18]. Report has shown that mycorrhizal fungi can connect the roots of different plants, allowing them to share resources and communicate with each other [19-21].

Organisms must swiftly and dynamically distribute information throughout their structures to adapt and react to shifts in their environment. When a segment of a plant faces stress, assault by other organisms, or other forms of danger, the data migrates to adjacent organs and even neighbouring plants, setting off appropriate countermeasures. This transfer of information hinges on the rapid movement of diminutive metabolites, hormones, proteins/peptides, RNAs, or volatile compounds. Additionally, electrical and hydraulic waves contribute to the spread of signals. These signalling agents traverse from one cell to an adjoining cell via plasmodesmata, across the apoplast, within the vascular tissue, or as airborne volatiles. Likely, crafting a response tailored to a specific threat in a systemic tissue necessitates a blend of diverse mobile compounds. As these signals must traverse lengthy distances and numerous barriers, the signal strength diminishes with distance. This necessitates ongoing amplification processes, loops of feedback, and cross-communication among distinct traveling molecules. A fleeting memory might also be necessary to rejuvenate the propagation process. Additional investigations underscore that volatile substances not only trigger defense reactions in systemic tissues but also serve vital roles in sustaining the advancement of traveling signals within the plant. Remote organs can promptly react to systemic signals or store information about threats, enabling faster and more potent responses upon subsequent exposure to the same or different hazards. However, as data is transmitted and stored, specificity regarding the initiating threat tends to erode [22].

In response to caterpillar feeding, plants emit volatile compounds that serve as attractants for the natural predators of these herbivores. This tri-trophic interaction is recognized as an indirect defense mechanism employed by plants against herbivorous insects. The volatile emissions triggered by caterpillar activity can either deter or entice conspecific adult herbivores. Despite the prevailing understanding, the precise volatile signals responsible for repelling or drawing in conspecific adults in real-world conditions remain unidentified. Notably, apple seedlings were observed to release a distinct array of seven compounds—namely, acetic acid, acetic anhydride, benzyl alcohol, benzyl nitrile, indole, 2-phenylethanol, and [E]-nerolidol—solely in response to infestations by light brown apple moth [*Epiphyas postvittana*] larvae. Through field trials conducted in New Zealand, a specific blend comprising benzyl nitrile and acetic acid exhibited a significant attraction to a substantial number of conspecific male and female adult moths. In the North American context, male and female adults of the tortricid species known as oblique-banded leafroller [*Choristoneura rosaceana*] displayed heightened attraction toward a blend of 2-phenylethanol and acetic acid. Similarly, both sexes of the eye-spotted bud moth [*Spilonota ocellana*] exhibited strong attraction to a blend of benzyl nitrile and acetic acid. This study marks a significant advancement by identifying caterpillar-induced plant volatiles that effectively allure conspecific adult herbivores within their natural environment. This finding challenges the prevailing assumption that herbivores generally avoid these volatiles produced in response to caterpillar activity [23]. The study also found that neighbouring tomato plants that were not directly attacked by the caterpillars increased their production of defensive chemicals in response to the volatile signals released by the attacked plants, providing evidence of interplant communication and the sharing of information about threats. These examples demonstrate the sophisticated and complex ways in which plants communicate with each other and their environment [24].

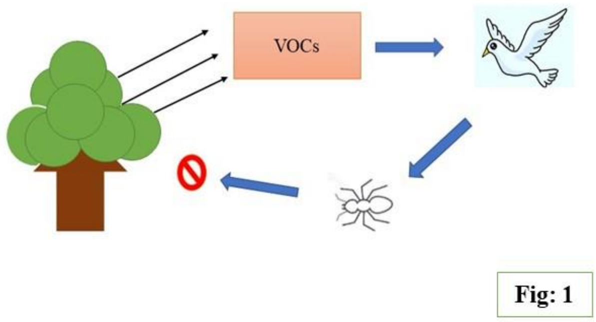
Type of plant's secret language: In the communication systems of plants, some examples of their secret language thought to be included:

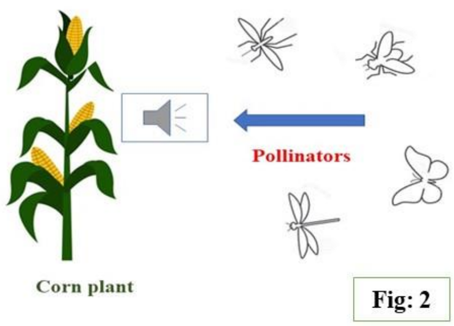
Chemical signals: Plants release chemicals called volatile organic compounds [VOCs] into the air to communicate with other plants, as well as with insects and other animals. For example, some plants release VOCs when they are attacked by insects, which can attract predatory insects that will attack the herbivorous insects (Fig 1). Plants can emit chemicals into the air to communicate with each other and with other organisms. For example, when a plant is attacked by an insect, it may release monoterpenes such as [E]-β-ocimene, [Z]-β-ocimene; sesquiterepenes as [E]-β-caryophyllene; homoterpene as [Z]-3-hexenyl acetate and others volatiles like 1-Octene-3-ol, benzyl alcohol that attract predators of the attacking insect, repel the insect itself, or warn neighbouring plants of the threat. A study by Karban and Shiojiri [2009] showed that sagebrush plants released volatile chemical name methyl jasmonate when attacked by herbivorous insects, which attracted insect predators and reduced herbivory [25, 26]. Certain plants like *Arabidopsis*, soybean could detect and react to elicitors such as β-Galactofuranose polysaccharide released by herbivores or molecules that are naturally present in plants. These elicitors trigger a variety of defense mechanisms within the plant that provide protection against predators [27]. Another study focused on the mechanisms by which plants sense herbivores and the signalling pathways, both within cells and between different parts of the plant, that are activated by elicitors. In response to infiltrations by herbivores or pathogens, plants activate specific defense mechanisms. If these invaders breach the initial defense, a secondary line of defense is initiated to counteract them, preventing extensive damage beyond the infection site. This secondary defense relies on the plant's ability to recognize pathogens and insects by detecting unique molecular patterns and secretomes linked to these intruders. These molecules interact with the plant's surface, amplifying received signals and initiating the transmission of plant-specific molecules. As a result, intricate signal pathways are activated, leading to the expression of defense and resistance genes, particularly in resistant plant varieties [28]. *Arabidopsis thaliana* is a model plant species that has been used extensively to study plant-insect interactions. Spodoptera moths are a group of agricultural pests that feed on a wide variety of plants, including *Arabidopsis*. The interactions between these two species are complex and involve a variety of chemical signals and defense mechanisms. *Arabidopsis* plants have a variety of defense mechanisms against Spodoptera moths, including the production of toxic chemicals, the accumulation of secondary metabolites, and the development of physical barriers. These defense mechanisms can be activated by the chemical signals produced by the moths. One of the most important chemical signals produced by Spodoptera moths is the alarm pheromone called hydroprene. Hydroprene is released by injured moths and attracts other moths to the site of the injury. It also causes the moths to become more aggressive and to feed more voraciously. Arabidopsis plants can detect hydroprene and respond by producing their own defense chemicals. One of these chemicals is jasmonic acid, which is a signaling molecule that activates a variety of defense responses. Jasmonic acid can also attract predators of Spodoptera moths, such as parasitic wasps. In addition to hydroprene, Spodoptera moths also produce other compounds that attract them to plants, such as indoles and terpenes. These compounds can also be detected by Arabidopsis plants and can trigger the production of defense chemicals. The defense mechanisms of Arabidopsis plants against Spodoptera moths are complex and involve a variety of chemical signals and pathways. These mechanisms have been studied extensively in order to develop new strategies for controlling these pests [29-31].

Sound waves: Some studies suggest that plants may produce and respond to sound waves, allowing them to communicate with each other. For example, a study by Mancuso *et al.,* [2017] showed that corn seedlings produced clicking sounds in response to simulated insect feeding- plants produce sounds that may help attract pollinators [32]. The researchers hypothesized that the sounds could be a way for the plants to communicate with each other or with insects (Fig 2).

Studies reveals that sound waves as plant's secret languages: Acoustic vibrations can induce defense responses in plants [33]. A study by Appel and Cocroft [2014] showed that plants can respond to the vibrations caused by insect herbivore chewing, triggering defense responses to deter further damage [34, 54]. Plants use sound waves to communicate with each other: Gagliano *et al.*, [2012] found that the roots of maize plants produce clicking sounds that can be detected by neighbouring plants, suggesting that they may use sound waves to communicate with each other [35]. Sound waves can indicate water stress in plants: Maia *et al.*, [2011] demonstrated that the acoustic emissions produced by water-stressed lupine plants differ from those of well-watered plants, suggesting that sound waves may be a useful indicator of plant water status [36]. Plants can detect airborne sound waves: Li *et al.*, [2018] showed that Arabidopsis plants can detect airborne sound waves in the frequency range of 100 Hz to 20 kHz, which could potentially serve as a means of communication or sensing environmental cues. These examples demonstrate the diverse ways in which sound waves can play a role in plant biology, from inducing defense responses to communicating with neighbouring plants and sensing environmental cues [37].

Root networks: Plants can also communicate through their root systems, which can form complex networks underground. Through these networks, plants can share nutrients, water, and even warning signals about potential threats in the environment [38]. A study showed that tomato plants could communicate with each other through their root systems, and that this communication could help them defend against diseases [39]. Plants use underground networks[mycorrhizal] to communicate with each other [40]. In the investigation conducted by Simard *et al.*, [1997], it was observed that paper birch trees employ a mycorrhizal fungi network for communication with neighboring trees. Through this network, they exchange nutrients and alert one another to potential threats, including insect attacks (Fig 3). Plants can use underground signals to coordinate their growth: a study by Falik *et al.*, [2005] found that the roots of sunflower plants can detect signals from neighbouring plants and adjust their own growth accordingly, suggesting that plants can coordinate their growth through underground communication [41]. Plants can use root exudates to signal to each other: Bais *et al.*, [2006] showed that plants can use different chemicals such as 7,8-benzoflavone, 8-Hydroxyquinoline, sorgoleone, 5,7,4'-trihydroxy-3',5'- Dimethoxyflavone, 7,8- benzoflavone, [±]-catechin, quinolines [8-hydroxyquinoline], and hydroxamic acids in their root exudates to signal to neighboring plants, attracting beneficial microbes or deterring pests [42]. Plants can use root networks to share resources: a study by Weiß *et al.*, [2019] found that root systems of different plant species can form networks to share nutrients, suggesting that plants can work together to optimize resource use in their environment. These studies demonstrate the diverse ways in which root networks can play a role in plant biology, from communication and coordination of growth to sharing resources and defending against threats [43, 44].





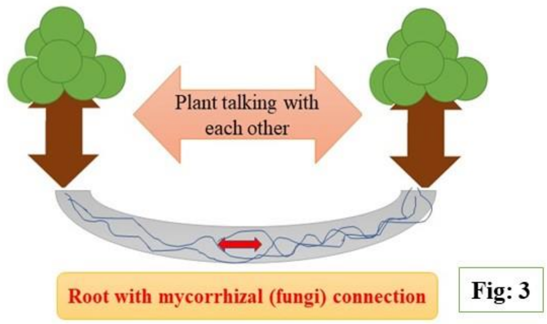


Fig1: Chemical signals as a secret plant's language

Fig 2: Sound wave as a secret plant's language

Fig 3: Root network as secret plant's language

Some chemicals involved in plant's secret language for communications: Plants use various chemical compounds to communicate with each other and with other organisms. These are just a few examples of the many chemicals that plants use to communicate with their environment.

Terpenes: Terpenes are a large class of volatile compounds that are commonly produced by plants. The dynamic connections between plants, their surroundings, and insects are reciprocal and ever-changing. This has led to the development of a multitude of mechanisms that facilitate various kinds of engagements between organisms. These connections often involve the use of allelochemicals, specifically volatile organic compounds [VOCs], which encompass volatile terpenes [VTs]. The release of VTs offers a means for plants to establish communication with their environment, encompassing nearby plants, beneficial creatures like pollinators and seed dispersers, as well as foes such as predators, parasitoids, and herbivores. Through this emission, plants transmit appealing or dissuasive cues, enabling intricate interactions [45, 46].

Methyl salicylate and Salicylic acid: This compound is a volatile organic compound that is produced by many plant species in response to herbivory or other types of damage. It can attract natural enemies of the herbivores, and induce defense responses in neighbouring plants. Salicylic acid is a signalling molecule that plays a key role in plant defense against pathogens. It is involved in the activation of defense genes and the production of secondary metabolites that help to protect the plant from infection [47].

Jasmonates: Jasmonates are a group of lipid-derived hormones that regulate many aspects of plant growth and development, including defense responses to herbivores and pathogens. Jasmonates are also involved in the communication between plants and beneficial microbes [48].

Ethylene: Ethylene is a gaseous hormone that regulates many aspects of plant growth and development, including fruit ripening and senescence. Ethylene is also involved in the response of plants to stress, such as drought and flooding [49].

Abscisic acid: Abscisic acid is a plant hormone that is involved in various processes, including seed dormancy, stomatal regulation, and response to environmental stress [50]. In response to drought, for example, plants produce more abscisic acid to close their stomata and reduce water loss. It can also mediate plant-plant communication during drought stress [51].

Strigolactones: Strigolactones are a group of plant hormones that play a role in plant development, including the regulation of shoot branching and root growth. They are also involved in the interaction between plants and symbiotic soil fungi, as well as in the communication between parasitic plants and their hosts. Strigolactones were initially discovered as germination stimulants for the parasitic plant Striga, but subsequent research has shown that they have a much broader range of functions in plants. They are produced in response to various environmental stimuli, such as low nutrient availability, and act as signaling molecules to regulate plant growth and development [52].

Flavonoids: Flavonoids are a diverse group of secondary metabolites that are involved in various plant functions, including UV protection, pigment production, and defense against pathogens and herbivores. Some flavonoids, such as quercetin and kaempferol, also act as signaling molecules to attract pollinators and seed dispersers [53].

Glutathione: Glutathione is a tripeptide that is involved in various cellular processes, including redox regulation and defense against oxidative stress. In plants, glutathione also plays a role in the response to biotic and abiotic stress, as well as in the regulation of plant growth and development [54].

Plants have evolved an intricate system of communication, often referred to as their secret language, which enables them to interact with their environment and other organisms. This language is essential for their survival, and recent research has shown that it can also be harnessed for conservation and medical purposes.

Plant's secret language for conservation, and medicine: In terms of conservation, understanding plant communication can help us to preserve biodiversity and protect endangered species. Many plants rely on pollinators such as bees, butterflies, birds, and bats for reproduction, and they have evolved various visual and olfactory cues to attract these pollinators. Flowers, through shapes, colours, and patterns, are tailored to specific pollinators, while unique scents guide them to the flowers. This comprehension of communication strategies enables conservationists to create landscapes and restoration initiatives that effectively support pollinators, contributing to the propagation of plant species. Beyond pollinator attraction, understanding plant communication aids in grasping the intricate interdependence of species within ecosystems. For instance, certain plants release soil chemicals that influence neighboring plant growth, crucial information for planning habitat restoration to enhance biodiversity. Decoding plant communication also provides valuable insights for restoration strategies. By identifying pivotal plant species and their interactions, conservationists can prioritize their reintroduction and use natural chemical cues to enhance restoration efforts. Furthermore, this understanding aids in addressing the impacts of climate change. As climate shifts disrupt plant-pollinator dynamics and ecosystems, insights into communication help predict imbalances, enabling proactive measures to counter changing environmental conditions [55, 57, 58].

Many of the chemicals that plants use to communicate with each other have been found to have medicinal properties. For example, the compound salicylic acid, which is produced by plants in response to stress, is the active ingredient in aspirin [59, 60]. Numerous plant compounds, including curcumin, gingerols, resveratrol, vincristine, vinblastine, betulinic acid, allicin, quercetin, and ellagic acid, exhibit diverse therapeutic potentials such as anti-inflammatory, anticancer, and antiviral properties, among other health-promoting effects [61, 62]. In this context understanding the plant's secret language has the potential to revolutionize conservation and medicine.

Table 1: Some common VOCs and their chemical pathways and functions in general plant communication

VOC	Chemical Pathway	Function in Plant Communication	References
Isoprene [C_5H_8]	Synthesized from isopentenyl diphosphate [IPP] via the MEP pathway.	Acts as an antioxidant, protecting plants from oxidative stress.	[61]
Terpenes	Synthesized from geranyl diphosphate [GPP] via the mevalonate pathway.	Attracts pollinators and deters herbivores.	[62]
Methyl Jasmonate	Derivative of linolenic acid.	Signals the presence of herbivores and induces defense responses.	[63]
Hexenal	Generated from fatty acids via the lipoxygenase pathway.	Acts as a signal for plant-to-plant communication during herbivore attacks.	[64]
Ethylene [C_2H_4]	Synthesized from methionine via the ethylene biosynthesis pathway.	Coordinates responses to environmental stress and ripening processes.	[65]
Green Leaf Volatiles [GLVs]	Generated from fatty acids via the lipoxygenase pathway.	Serve as infochemicals to warn neighboring plants of herbivore attacks.	[64]
Dimethyl Sulfide [DMS]	Synthesized from methionine via the methionine degradation pathway.	Attracts herbivore predators and serves as a cue for herbivore presence.	[65]

Table 2: Some of the chemicals involved in function of plant's secret language for communications

Chemical	Function in Plant Communication	References
Jasmonic Acid [JA]	Signaling molecule in response to herbivore and pathogen attacks, induces defense genes.	[66]
Salicylic Acid [SA]	Involved in systemic acquired resistance against pathogens.	[67]
Abscisic Acid [ABA]	Mediates responses to environmental stress, such as drought.	[68]
Gibberellins [GA]	Regulate plant growth and development, including stem elongation.	[69]
Ethylene [C_2H_4]	Regulates fruit ripening, senescence, and stress responses.	[65]
Auxins [e.g., IAA]	Control various aspects of plant growth, including tropisms.	[70]
Cytokinins [CKs]	Promote cell division and regulate plant growth and development.	[71]
Strigolactones [SLs]	Induce the germination of parasitic plants and modulate root development.	[72]
Brassinosteroids [BRs]	Influence cell elongation, vascular differentiation, and stress responses.	[73]
Indole-3-Acetic Acid [IAA]	A major auxin involved in plant growth and development.	[74]
Methyl Salicylate	Volatile form of salicylic acid, involved in plant-to-plant signalling during pest attacks.	[75]
Cis-Jasmone	Released by damaged plants to signal herbivore presence and attract natural enemies.	[76]
Phytoalexins	Antimicrobial compounds produced in response to pathogen infection.	[77]
Nitric Oxide [NO]	Functions in diverse plant processes, including defense responses.	[78]
Hydrogen Peroxide [H_2O_2]	Signalling molecule in response to abiotic and biotic stress.	[79]
Phenylpropenes	Defensive compounds against herbivores and pathogens. Floral attractants for pollinators and to have antifungal and antimicrobial activities	[80]
Glucosinolates	Compounds involved in plant defense against herbivores and pathogens.	[81]
Volatile Organic Compounds [VOCs]	Emitted by plants to communicate with other plants and attract pollinators.	[82]

The Significance of Plant Communication:

The pivotal role of plant communication is vividly illustrated by the interconnected network of plants. This communication network, facilitated by signalling molecules in the soil, fosters ecological harmony by promoting mutual growth, enhancing nutrient exchange, and signalling against pests. Additionally, it serves as a crucial component of stress response, aiding adaptive survival strategies during environmental changes. Plant communication extends beyond ecological realms, facilitating symbiotic relationships with other organisms and presenting agricultural benefits such as improved disease resistance and nutrient absorption. Moreover, its impact on human well-being is notable, offering potential medicinal properties. Thus, plant communication emerges as a linchpin in ecological balance, stress resilience, agricultural optimization, and human-health connections, emphasizing its broad significance across diverse contexts (Fig 4).

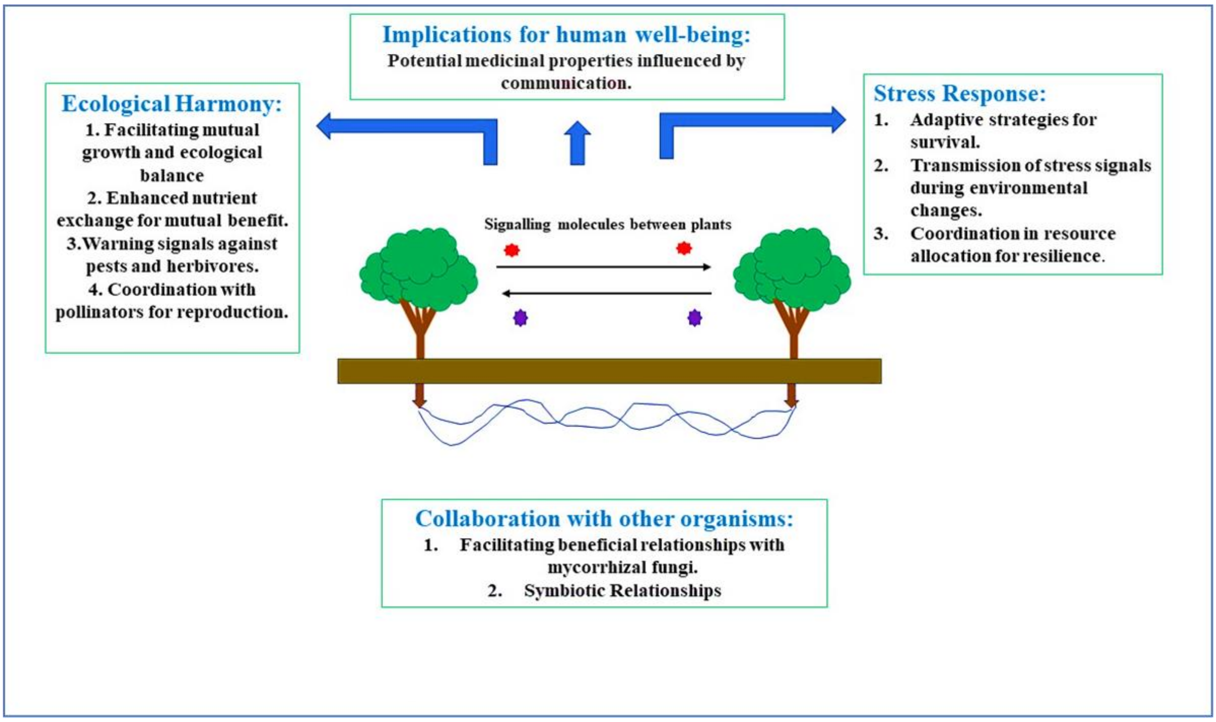


Fig 4: The Significance of Plant Communication

CONCLUSION

Plants' ability to communicate with each other through chemical signals and even sound waves is a topic of ongoing research and debate. Despite the lack of conclusive evidence, there is no denying that plants are intelligent and have evolved intricate ways of surviving in their environments. By better understanding the mechanisms behind plant communication, we can develop new technologies and strategies for improving crop yields, protecting endangered species, and combating climate change. The secretion and reception of chemical compounds, such as terpenes, jasmonates, and flavonoids, allow plants to regulate their growth and development, defend against herbivores and pathogens, and attract pollinators and seed dispersers. Plant communication is a crucial area of research with potential applications in agriculture, conservation, and medicine. By delving deeper into the secret language of plants, we can unlock new insights into the natural world and gain a better understanding of the complex and intelligent organisms that surround us.

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