International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 15-10-2021, Accepted: 01-11-2021, Published: 16-11-2021
Volume 6, Issue 6, 2021, Page No. 343-348

A review on data collection and documentation studies in plant to plant communication

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Abstract
The key point in communication is "Exchange of information". Plants communicate with other plants to get a proper understanding about their surroundings, sense threats and ultimately share 'information'. In the present study is based on studies conducted in the world related to plant to plant communication, describing different modes of plant to plant interaction. The current studies reveals that there are several modes by which plant to plant communication occurs namely, mycorrhizal networks, volatile organic compounds (VOCs), electrical signaling, etc. Several researchers have concluded that plants can transport nutrients such as carbon and nitrogen from one plant to another through mycorrhizal connections between the roots of neighbouring plants [16]. Studies have also been conducted on how plants warn their neighbors by producing volatile organic compounds when they sense attack by herbivorous animals [17]. This study aims to collecting and documenting the instances that revels plants, like other animals can also communicate. This study also deep dives into the effect that deforestation has caused to lack of means of communication between mother trees and seedlings, that ultimately results in biodiversity loss.

Keywords: mycorrhizal networks, volatile Organic compounds

Introduction

There are several ways by which plants communicate with each other. One of the common ways is by emitting volatile organic compounds. This communication has a tremendous influence which helps the plants and the organisms for their growth, development, defence, propagation and life cycle to attain maximal fitness. Mutualists like pollinators, and antagonists such as herbivorous insects use the unique volatile blend produced by the plants for the identification and housing with in a host. The host blend involves both major and minor components, but the most plentiful compounds do not automatically determine the response to the entire world [3]. Another form of communication with plants takes place via their complex root networks. Through roots, plants can share many different resources including nitrogen, fungi, nutrients, microbes, and carbon. This transfer of below ground carbon is examined in [16]. The goals of this paper were to test if carbon transfer was bi-directional, if one species had a net gain in carbon, and if more carbon was transferred through the soil pathway or common mycorrhizal network (CMN).

Unstressed plants demonstrated the ability to sense and respond to stress cues emitted from the roots of the osmotically stressed plant. Furthermore, the unstressed plants were able to send additional stress cues to other neighboring unstressed plants in order to relay the signal [1]. A cascade effect of stomatal closure was observed in neighboring unstressed plants that shared their rooting system but was not observed in the unstressed plants that did not share their rooting system. Therefore, neighboring plants demonstrate the ability to sense, integrate, and respond to stress cues transmitted through roots. Did not identify the chemical responsible for perceiving stress cues, research conducted in 2016 by [7] suggests several possibilities. They found that plant roots synthesize and release a wide array of organic compounds including solutes and volatiles (i.e. terpenes). They cited additional research demonstrating that root-emitted molecules have the potential to induce physiological responses in neighboring plants either directly or indirectly by modifying the soil chemistry. Plants also communicate via electrical signals, which is explored in [5]. These electrical signals are mediated by cytosolic Ca^{2+} ions. Cytosolic calcium signals are mediated by hundreds of protein and protein kinases, and many of the signals also induce action potentials in plants.

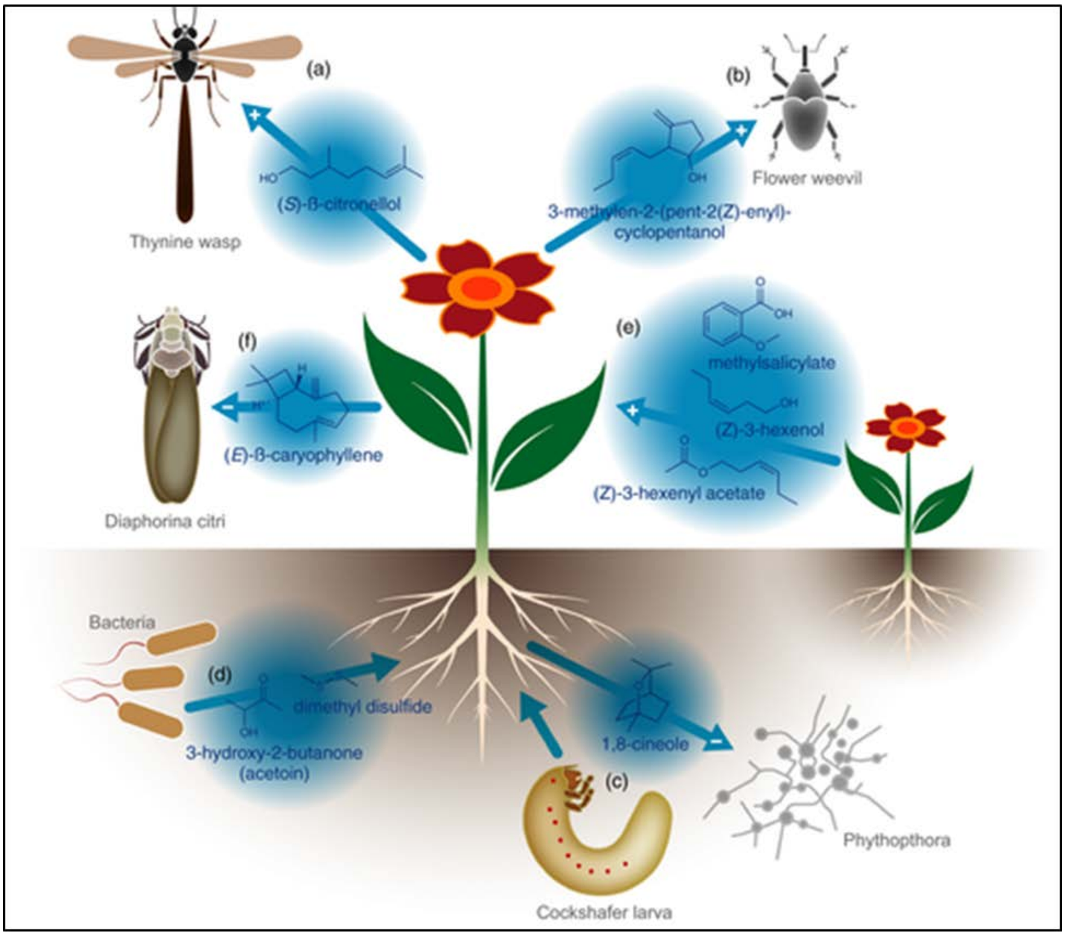

Fig 1: Chemical communication between plants and other organisms [24]

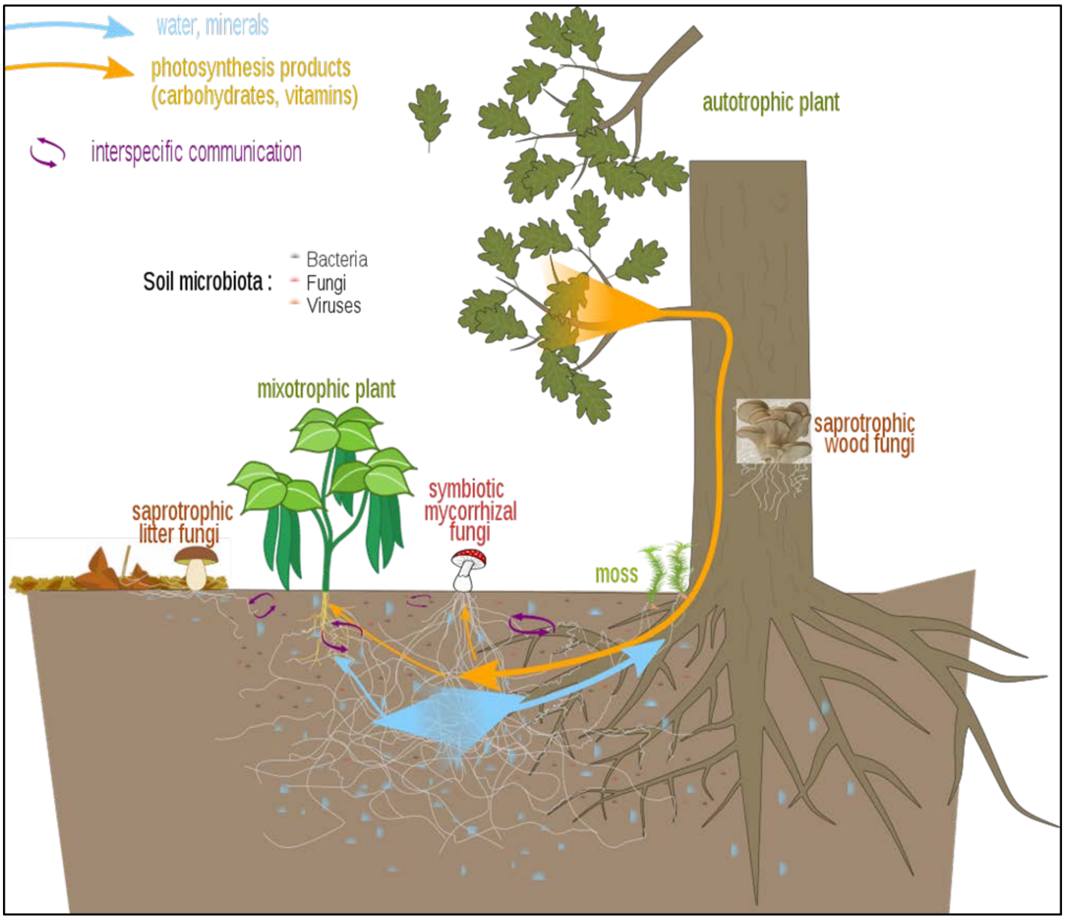

Fig 2: Nutrient exchanges and communication between mycorrhizal fungi and plants [25]

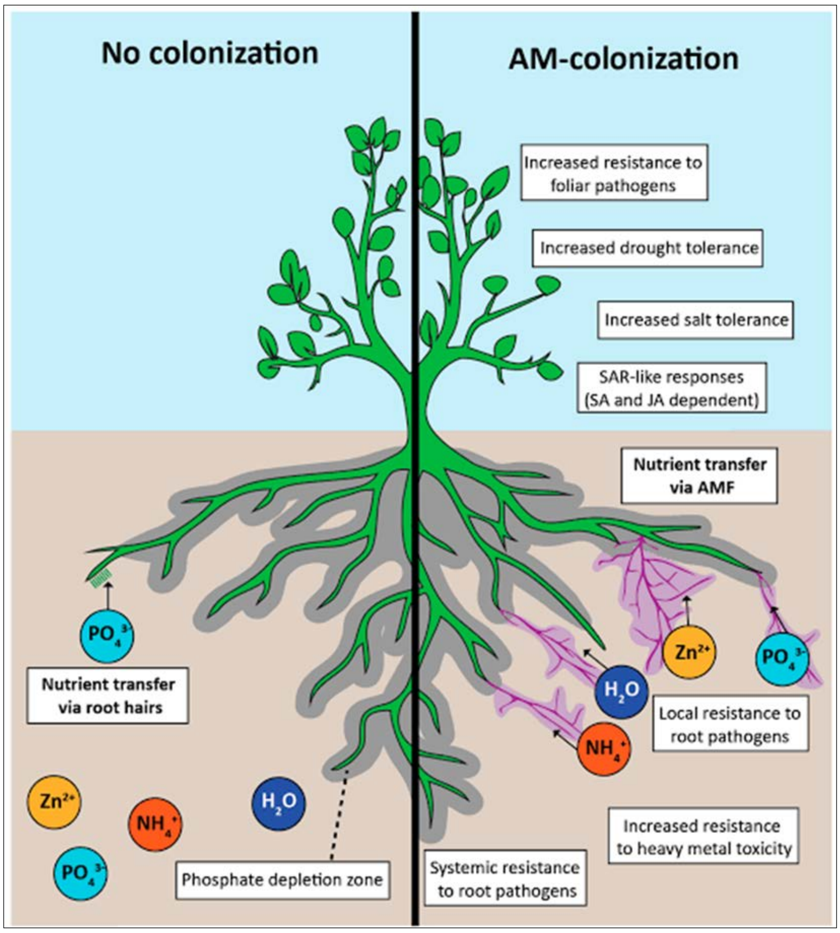

Fig 3: Arbuscular Mycorrhizal association [26]

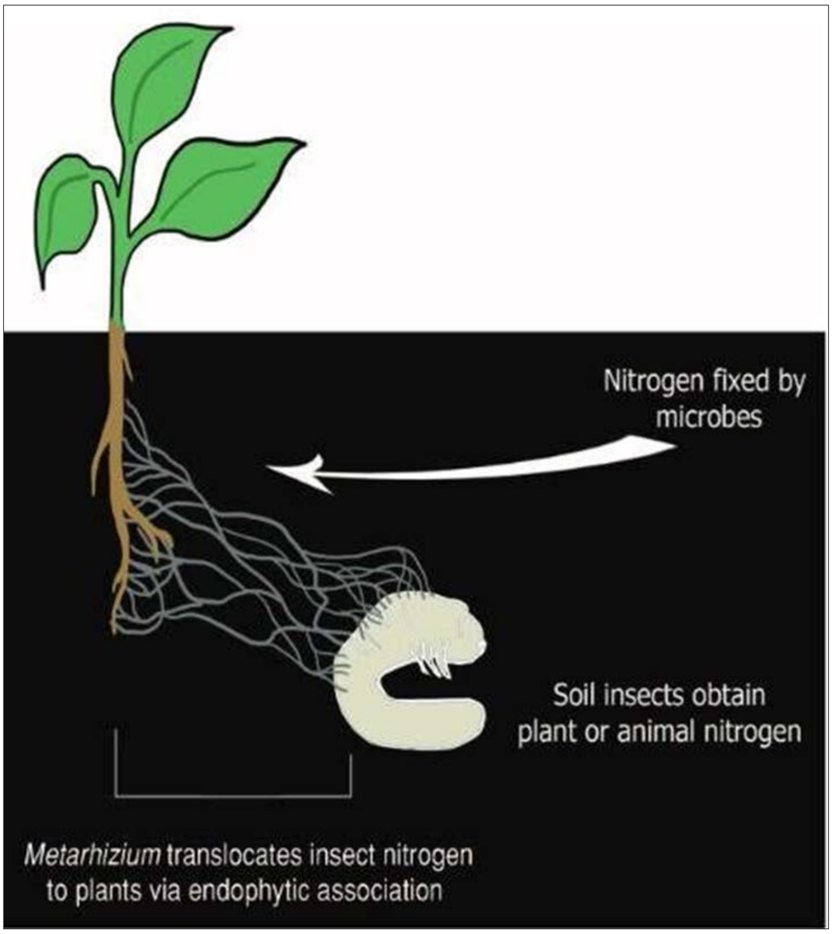

Fig 4: In Defence of Plants [27]

Materials and Methods

In the present study data collection method is used to analyse plant to plant communication from various sources and regions. An extensive study is conducted to classify and document the various modes by which plants communicate with each other. It includes, the importance of communication between mother trees and seedlings in ecological balance, ground communication of higher plants through ectomycorrhizal networks. To study the volatile chemical message transfer among plants as well as electrical signaling means of communication in plants. The work was completed by obtaining data from journals, periodicals and the internet.

Results and Discussion

Table 1: Emitter, receiver and the response produced by the plant as a result of communication

Emitter	Receiver	Response	Reference
Poplar (*Populus deltoides x nigra*)	Poplar (*Populus deltoides x nigra*)	Within-signalling by VOCs provides resistance to gypsy moth larvae.	[17]
Lima bean (*Pha-seolus lunatus*)	Lima bean (*Pha-seolus lunatus*)	Gene expression after exposition to VOCs.	[12]
Barley (*Hordeum vulgare*)	Thistle (*Cirsium arvense* and *Cir-sium vulgare)*	Reduced attraction of aphids	[15]
Tobacco (*Nicotiana tabacum*)	Tobacco (*Nicotiana tabacum*)	Resistance to tobacco mosaic virus and expression of resistance genes	[4]
Cotton (*Gossypium hirsutum*)	Cotton (*Gossypium hirsutum*)	Resistance to spider mites and attraction of predatory mites	[8]
Sagebrush (*Arte misia tridentata*)	Tomato (*Lyco persicon esculentum*)	Synthesis of pro teinase inhibitors	[10]
AtCNGC2 locus (Ca2+ ions)	*AtCNGC2* locus	resistance to avirulent *Pseudomonas syringae* as well as a range of virulent pathogens	[11]
Sugar maple (*Acer saccharum*)	Sugar maple (*Acer saccharum*)	Increased content of phenolic compounds	[9]
Wilow (*Salix sitchensis*)	Wilow (*Salix sitchensis*)	Resistance to natural herbivory	[20]
Alder (*Alnus glutinosa*)	Alder (*Alnus glutinosa*)	Increased resistance to natural herbivory	[21]
Corn (*Zea mays*)	Corn (*Zea mays*)	Priming of JA synthesis and VOCs release	[22]
Arabidopsis thaliana	*Arabidopsis thaliana*	Changed expression of hundreds of plants	[23]

Like humans, closeness and avoidance are expressed by plants as well. Inter and intra specifically, friendly and definite talk was seen in plants. The definition of communication as exchange of information, however, is not the one used by most evolutionary biologists, for whom it is important to adopt a pragmatic view that distinguishes between evolved functions and incidental effects [34]. The number of reports on plant-plant communication is increasingly rapidly (Table 1). Undamaged Poplar (*Populus × euroamericana)* increased their anti-herbivore defense when exposed to air around damaged, resistance- expressing plants. It was postulated that the attacked plants had 'warned' their neighbours [17]. Lima bean (*Phaseolus lunatus)* had also become a model system for studying plant communication. In this case, increased expression of defense related genes in plant when infestation with spider mites [12]. In addition, Barely (*Hordeum vulgare*) plants became less attractive to aphids after exposure to air from various thistle species, an effect that can protect Barely under field conditions. Interestingly, Barely responds to VOCs released from intact plants, which can be thistles or other Barely cultivars [15]. Several field experiments conducted in Tobacco (*Nicotiana tabacum*). Tobacco plants experienced less natural damage by herbivores when grown in close proximity to experimentally clipped neighbours. Plant resistance to Tobacco Mosaic Virus due to the expression of resistance genes [4]. In Cotton (*Gossypium hirsutum*) plants increased attraction of predatory mites, reduced oviposition by herbivores mites [8]. In Sage brush (*Artemisia tridentate*), plants synthesise proteinase inhibitors towards Tomato (*Lycopersicon esculentum*) [10]. Response towards the resistance to avirulent *Pseudomonas syringae* as well as a wide range of virulent pathogens by *AtCNGC2* locus [11]. In Sugar maple (*Acer saccharum*) plants response to increased contetnt of phenolic compounds [9]. In case *Salix stichensis*, growing close to herbivore-infested conspecifies were reported to express higher levels of resistance to herbivores than did plant that were growing further away [20]. Several field experiments conducted during the 1990s indicated that Alder trees (*Alnus glutinosa*) experienced less natural damaged by herbivores when grown in close proximity to experimentally clipped neighbours [21]. Air coming from the induced plants trigger phenotypic resistance and the expression of resistance related genes in intact plants has now been reported in Corn (*Zea mays)* [2] and *Arabidopsis thaliana* [23].

Plants may "eavesdrop" on volatile organic compounds (VOCs) released by herbivore attacked themselves. Advances in research on VOC biosynthesis and perception have facilitated the production of plants that are genetically "deaf" to particular VOCs or "mute" in elements of their volatile vocabulary. Such plants, together with advances in VOC analytical instrumentation, will allow researchers to determine whether fluency enhances the fitness of plants in natural communities [18]. Common mycorrhizal networks connecting trees of the same species will transfer less recently photosynthesized carbon than those of differing species [19]. Connection to mycorrhizal networks creates positive feedbacks between adult trees and seedlings of the same species and can disproportionately increase the abundance of a single species, potentially resulting in monodominance. Monodominance occurs when a single tree species accounts for the majority of individuals in a forest stand. [6], working with the monodominant tree *Dicymbe corymbosa* in Guyana demonstrated that seedlings with access to mycorrhizal networks had higher survival, number of leaves, and height than seedlings isolated from the ectomycorrhizal networks.

Plants may lack brains, but they have a nervous system. And now, plant biologists have discovered that when a leaf gets eaten, it warns other leaves by using some of the same signals as animals. The new work is starting to unravel a long-standing mystery about how different parts of a plant communicate with one another. Animal nerve cells talk to each other with the aid of an amino acid called glutamate, which—after being released by an excited nerve cell—helps set off a wave of calcium ions in adjacent cells. But scientists were investigating how plants react to gravity. They developed a molecular sensor that could detect increases in calcium, which they thought might play a role. They bred the sensor, which glows brighter as calcium levels increase, into a mustard plant called *Arabidopsis*. They then cut one of its leaves to see whether they could detect any calcium activity. They immediately saw a glow that got brighter, then dimmer, right next to the wound; then the glow appeared and disappeared farther away until the wave of calcium reached the other leaves. This clearly states that a plant has nervous system similar to other animals that helps in communication using calcium ions. These signals can also be propagated to other plants with the help of roots. Plants can use volatile organic compounds released from herbivore-infested neighbours to anticipate future enemy pressure and adjust their defensive phenotype accordingly. The most likely explanation for the evolution of this phenomenon is that plants use volatile signals for within plant signalling, that is, to mount a systemic response to local damage in undamaged parts. The benefits of this within-plant signalling are obvious and the same remains true for the receivers of VOC that allow them to anticipate upcoming enemy attack. By contrast, no study has demonstrated that the emitting plant benefits from warning its neighbours. The question remains open whether this signalling phenomenon represents communication or, rather, eaves dropping. Action potential occurs in plant cells is an another way of plant communication. Plant don’t have nerves, plants cells are capable of generating electrical impulses called action potentials. Some carnivores plants like *Venus flytrap*, *Mimosa pudica*, Telegraph plant, Sundews and Bladderworts creates rapid movement through action potential. The mechanism by which the trap snaps shut involves a complex interaction between elasticity, turgor and growth [37]. Action potential and mechano-sensitive signals are important communication mechanisms in plants. The effective range of multiple action potentials for a long chain of cells in different configurations and introduces the study of multiple mechano-sensitive activation signals in plants [38].

Conclusion

Plants can be exposed to many stress factors such as disease, temperature changes, herbivory, injury and more. Therefore, in order to respond or be ready for any kind of physiological state, they need to develop some sort of system for their survival in the moment and for the future. Plant communication consists of communication using volatile organic compounds, electrical signaling, and common mycorrhizal networks between plants and a host of other organisms such as soil microbes, other plants of the same or other species, animals, Insects, and fungi. The researchers demonstrate how the parasitic plant *Cuscuta pentagona* (dodder weed) uses VOCs to interact with various hosts and determine locations. Dodder seedlings show direct growth toward tomato plants (*Lycopersicon esculentum*) and specifically elicited tomato plant volatiles. Another form of plant communication occurs through their complex root networks. Through roots, plants can share many different resources including nitrogen, fungi, nutrients, microbes, and carbon. This transfer of below ground carbon [12]. Plants also communicate via electrical signals [15]. These electrical signals are mediated by cytosolic Ca2+ ions. Cytosolic calcium signals are mediated by hundreds of protein and protein kinases, and many of the signals also induce action potentials in plants.

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