

Silent Signals: A Review on Exploring the Science of Plant Communication

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ABSTRACT

Plants, once perceived as silent and passive organisms, are now emerging as active, communicative beings deeply attuned to their environment. This review explores the intricate and often invisible ways in which plants communicate—not through speech, but via chemical signals, electrical impulses, airborne scents, and subterranean fungal networks. Through examples such as herbivore-induced volatile emissions that summon predatory allies, and underground mycorrhizal exchanges that foster resource sharing and immune priming, this paper reveals a complex language of survival and cooperation. Understanding these silent conversations not only challenges our conventional notions of intelligence and behavior but also presents transformative opportunities in sustainable agriculture, ecological restoration, and plant biotechnology. By listening more closely to the plant world, we may uncover nature's most ancient and subtle wisdom.

Keywords: Plant communication, chemical signaling, volatile organic compounds, electrical signaling, mycorrhizal networks, plant-microbe interaction, systemic signaling, sustainable agriculture, plant behavior, plant intelligence.

INTRODUCTION

Imagine walking through a dense forest, where the trees stretch towards the sky and a soft breeze carries the scent of moss and leaves. Undiscovered to the casual observer, a silent but sophisticated network of communication is constantly at play beneath and above the forest floor. Trees are not just passive pillars of wood and chlorophyll—they are engaged in continuous, complex interactions with each other and their environment. They can warn neighboring plants of herbivore attacks, send distress signals when under drought stress, and even share nutrients through underground root-fungal systems known as the mycorrhizal network.

Despite lacking a nervous system or consciousness as we understand it, plants exhibit a form of intelligence rooted in their ability to perceive, assess, and respond to environmental cues. Through volatile organic compounds, electrical signals, hydraulic changes, and biochemical feedback loops, plants 'speak' in a language that is ancient, non-verbal, and astonishingly effective.

This paper delves into the fascinating realm of plant communication. It brings together recent research and emerging theories to explore how plants detect and transmit information. By uncovering the silent signals exchanged between roots, stems, leaves, and even across species, we gain a deeper appreciation of plant behavior—and of the complex ecological webs they help sustain. In doing so, we also begin to reframe our own understanding of communication, cognition, and cooperation in the natural world.

Chemical Signaling in Plants:

Plants rely heavily on chemical messages to survive and thrive.

- **Phytohormones:** Think of these as the internal messengers of a plant's body. For example, when a caterpillar chews on a leaf, the plant ramps up production of jasmonic acid, which sends a signal to activate defenses like bitter-tasting compounds to deter the invader.
- **Allelochemicals:** Some plants send out chemical 'keep out' signs. The black walnut tree, for instance, releases juglone into the soil, a toxin to other plants trying to grow nearby.
- **Root exudates:** Plants also talk to microbes. Legumes release flavonoids from their roots to attract rhizobia, bacteria that help them fix nitrogen—an essential nutrient.

Volatile Organic Compounds (VOCs) Plants can send messages through the air using scents.

- **Herbivore-induced volatiles:** When maize is attacked by caterpillars, it emits a cocktail of smells that attract parasitic wasps—natural enemies of the caterpillars.
- **Pollinator attraction:** Flowers woo pollinators with fragrances. Orchids are especially clever; some even mimic the pheromones of female insects to lure in males.
- **Stress signaling:** Under stress—like a drought—plants can release certain VOCs that warn their neighbors to prepare themselves, a bit like shouting "brace yourself!"

Electrical and Hydraulic Signaling Plants can also use electricity and water pressure to send messages quickly over long distances.

- **Action potentials:** The Mimosa pudica, known as the "touch-me-not," closes its leaves instantly when touched, thanks to electrical impulses that travel through its tissues.
- **Wound responses:** When injured, plants send electrical alerts through their phloem (a kind of vascular tissue), warning distant parts of the plant to boost their defenses.
- **Hydraulic changes:** Drought stress can alter internal water pressure, triggering stomata (tiny pores) to close and conserve moisture.

Mycorrhizal Networks and Rhizosphere Interactions Underground, plants are connected by fungi in what some scientists call the "Wood Wide Web."

- **Nutrient exchange:** Mycorrhizal fungi help plants access nutrients like phosphorus. In return, plants feed the fungi sugars.
- **Sharing warnings:** If one plant is infected by a pathogen, others connected through fungal networks often activate their own defenses before the threat reaches them.
- **Helping the young:** In forests, large trees can send carbon to shaded saplings, nurturing the next generation.

Plant-Microbe Communication Plants are constantly in dialogue with microbes in their environment.

- **Legume partnerships:** When legumes send out flavonoids, rhizobia respond with Nod factors that cause the plant roots to form nodules—little homes where the bacteria can live and help fix nitrogen.
- **Calling fungi:** Strigolactones secreted by roots attract mycorrhizal fungi and trigger them to grow toward the plant.
- **Recognizing enemies:** Plants have built-in immune sensors. For example, Arabidopsis detects a bacterial flagellin protein using its FLS2 receptor and mounts a defense.

Ecological and Agricultural Implications Harnessing plant communication can lead to smarter farming.

- **Priming immunity:** Farmers can use certain compounds to pre-alert plants to pests, reducing the need for chemical pesticides.
- **Strategic planting:** Companion planting—like growing Desmodium with maize—can repel pests naturally.
- **Better biofertilizers:** Encouraging healthy microbial communities improves soil fertility and plant health.
- **Breeding better crops:** Plants with enhanced communication skills could be more resilient to stress and disease.

Challenges and Future Directions The language of plants is still being decoded.

- **Too many signals:** Plants often use overlapping signals, making it hard to understand what's being said.
- **Environmental noise:** Conditions like temperature and light can affect how signals are produced or perceived.
- **Making it practical:** Translating this knowledge into real-world farming systems takes time and innovation.

Future advances could come from:

- High-tech tools like biosensors and synthetic biology to observe or tweak plant communication.
- Modeling ecosystems to predict how plants will behave or react.

CONCLUSION:

In conclusion, the once-overlooked world of plant communication opens a new frontier in our understanding of life on Earth. What we once considered silent and passive organisms are now recognized as sensitive, responsive, and interconnected beings. Through invisible chemical messages, subtle electrical pulses, and the vast fungal networks beneath our feet, plants are constantly exchanging information — about danger, resource availability, and environmental changes. These discoveries reveal a quiet yet sophisticated system of collaboration and resilience, where survival is often based on mutual support rather than competition.

Acknowledging and understanding this hidden language of plants does more than satisfy scientific curiosity — it reshapes our relationship with the natural world. It teaches us that intelligence and communication come in many forms, some of which require us to expand our definition of sentience and awareness. More importantly, it urges us to shift from a human-centered view of nature to one that recognizes the intrinsic value and wisdom of all life forms.

As we face global challenges such as climate change, biodiversity loss, and food insecurity, the lessons embedded in plant behavior offer vital clues. Learning from how plants sustain themselves, adapt to adversity, and maintain balance within ecosystems can inspire innovative, sustainable practices in agriculture, conservation, and urban planning.

Ultimately, by tuning into the whispers of the plant world, we don't just unlock scientific knowledge — we reconnect with a deeper ecological consciousness. In this quiet dialogue between humans and nature lies the promise of a more harmonious and resilient future. It is time we stop seeing plants as mere background to our lives and begin honoring them as vital partners in the shared journey of life on Earth.

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