

Phytosemiotics

Decoding the Secret Language of Plants

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WHO doesn't like the smell of the first rain — such an enticing scent. This refreshing aroma has a formal name, "Petrichor", which in Greek translates to the "ether of rocks".

Science as early as the 1960s revealed that this scent is a combination of three distinct substances in the air that get released from the soil when the season's first raindrops hit it. First, a mixture of two volatile plant oils, stearic acid and palmitic acid, which the plants released during the dry season preceding the first rain. When the rain hits the dry earth, these oils transfer from the soil to the air. Second, a volatile organic molecule called geosmin is released by Actinomycete bacteria like *Streptomyces* and a few soil-inhabiting cyanobacteria. Finally, the third is the ozone molecule, formed in the lightning and brought down by rain droplets. The earthy, musty, and pleasant smell of petrichor is a combination of these three substances getting into our noses.

Just like petrichor, another unforgettable smell for many of us is the scent of cutting grasses. But, however pleasing it may seem to us, the smell is a distress signal for the grass. The scent is due to a group of compounds called Green Leaf Volatiles (GLVs), primarily a combination of aldehydes, alcohols, esters, and ketones. These molecules can trigger wound-healing responses in the cut parts of plants, which help the plants to heal faster. In addition, these compounds also have antibacterial and antifungal properties that contribute to minimizing the chances of infection in wounds.

A recent study found that GLVs can indirectly act as pesticides (Allmann and Baldwin 2010). This is because as GLVs get in the saliva of the caterpillar — the pest — the caterpillar becomes more attractive to its natural predators — Geocoris insects. The Geocoris eats the caterpillars, helping the plants to get rid of this pest. GLVs are also precursors to Ozone, which is a known pollutant in the lower atmosphere. GLVs can also cause urban smog during winter, significantly decreasing visibility (Kirstine, Galbally et al. 2002). This is one reason for the rampant smog episodes during winters across north India.

Research on petrichor and GLVs are examples of an enthralling field of science, phytosemiotics, the study of plant communication. The area emerged as a fringe idea in the 1980s when scientists conjectured trees communicate with each other via "W-waves" — the language of trees, a notion quickly discounted as pseudoscience by established scientists.

Remember that Indian polymath Jagadish Chandra Bose did pioneering studies on the electrophysiology of plants since the 1900s and believed that plants have feelings like us. Bose

worked on two plants, the touch-me-not *Mimosa pudica* and the telegraph plant *Desmodium gyrans*. His research revealed that these plants respond to multiple stimuli, such as touch and wound, via electrical impulses, which is very similar to the nervous system of animals.

JC Bose's book *Nervous System of Plants* published in 1926 was well received by scientists worldwide. He also invented the crescograph — an instrument to measure plant responses to various stimuli.

Recent research has revealed molecular mechanisms of Bose's 120 years old findings, which surprisingly uncovered more parallelism with animals as Bose conjectured years ago.



Jagadish Chandra Bose

Source: Wikimedia



Giraffes grazing on acacia at San Francisco Zoo

In humans and other animals, nerve conduction is mediated by an amino acid called glutamate. For instance, when you attempt to move your fingers, the neuron responsible for this action releases a glutamate molecule into the synapse — the junction between two adjacent neurons. This triggers a series of calcium waves that result in the transmission of an electrical signal to the fingers and, ultimately, muscle movement in the finger, all happening within a fraction of a second. New research confirms that electrical conduction within plants is also mediated by glutamate, triggering calcium waves (Toyota, Spencer *et al.* 2018).

The most inspiring arena of phytosemiotics is exploring communication between plants. It is long known among African tribespeople that giraffes always eat branches of Acacia trees facing the wind. That is, giraffes graze the acacias upwind, towards where the wind comes from, and walk towards the wind, not away from it. Recent research has revealed the curious reason for this behavior. Giraffes figured out acacia trees communicate downwind. While humans learned about the secret language of plants only very recently, giraffes and possibly other animals knew it all along! When a grazing giraffe injures an acacia tree, the plant releases ethylene, a Volatile Organic Carbon (VOC), into the air. Ethylene is a communication agent to alert nearby acacia trees about the impending danger, which triggers the plants to release tannins into their leaves. Tannins are bitter and poisonous even for more giant herbivores like antelopes. Studies suggest ethylene released by acacia trees can travel up to 50 meters, and trees exposed to these start pumping tannins 20 times the usual concentration within 30 minutes of exposure (Yam 1990). As ethylene from injured acacia leaves travels by wind, plants from upwind areas are not exposed to this volatile molecule, and their leaves remain delicious to the giraffes. Millions of years of natural selection resulted in the giraffes in the African savanna having ‘learned’ this form of plant communication to evade the communication by grazing upwind.

Like acacia trees, several plant species have developed similar communication systems to warn their

neighbours about herbivore attacks. For instance, Lima beans (*Phaseolus lunatus*), corn seedlings, sugar maples (*Acer saccharum*), poplars and willow trees, revealed by research as early as in 1983.

Sugar maple trees with the caterpillar-caused injury can trigger neighbouring trees to boost tannin production (Rhoades 1983). When beetles graze on Lima beans, other Lima bean plants in the vicinity respond by growing faster and resisting future attacks. When beet armyworms (*Spodoptera exigua*) attack maize plants, the GLVs released by the mature plants trigger corn seedlings to ‘remember’ this so that as it grows, they can produce effective biochemicals to ward off future attacks (Engelberth, Alborn *et al.* 2004). When injured, Sagebrush plants release a VOC called methyl jasmonate, which warns nearby sagebrush plants to produce the defensive enzyme polyphenol oxidase.

Plants can also communicate with other species of plants — the so-called inter-specific communication. Tobacco plants (*Nicotiana tabacum*) in the vicinity of injured sagebrush plants also respond to the danger signal via VOCs released by the latter by producing more polyphenol oxidase enzymes (Karban, Maron *et al.* 2003). Similarly, injured cucumber plants (*Cucumis sativus*) have also been found to be communicating with other species nearby, like chilli peppers (*Capsicum annuum*) and Lima beans, to trigger defensive responses in them as well.

Apart from plants communicating with other plants, research has also revealed plant-animal communications. For instance, when beet armyworms are attacked, maize plants release a VOC called volicitin into the air (Alborn, Turlings *et al.* 1997). The scent of this volicitin attracts wasps — the natural predators of caterpillars of beet armyworms so that wasps feed on the pests.

Remember the geosmin that we introduced early on in this article — a component of petrichor? A recent report revealed that releasing geosmin is an adaptation for the bacteria to spread into more environments (Becher, Verschut *et al.* 2020). This is because tiny insects called springtails get

attracted to the smell, which then eat these bacterial masses. Bacterial spores — the seed-like cells that develop into mature bacteria — get attached to the body of springtails and get into their digestive system. Subsequently, spores get dispersed to a vast region through their body and faeces, just like pollinators like bee aid in the reproduction of plants by letting the pollen stick to their belly. Bacteria-Insect communication mediated through geosmin has resulted from millions of years of natural selection.

The VOCs released by plants play a crucial role in planet-wide weather patterns. Coccolithophores — especially *Emiliania Huxleyi* — a unicellular planktonic algae — release massive amounts of Dimethyl Sulphide (DMS) when stressed. This volatile molecule in the air functions as cloud condensation nuclei triggering the formation of clouds. DMS-nucleated clouds are responsible for a number of inter-continental weather patterns, including Indian monsoon rains.

Apart from communicating via VOCs through the air, plants can also communicate via sound, as crazy as it seems. A 2019 preprint paper describes how plants emit high-pitch ‘clicks’ when stressed (Khait, Lewin-Epstein *et al.* 2019). Another recent study revealed that the evening primrose plant (*Oenothera drummondii*) increases sugar in the nectar of its flowers when exposed to the mere sound of flying pollinators (Veits, Khait *et al.* 2019). Studies in this area have been scanty, therefore, possess great opportunities for future researchers.

Perhaps the most prominent mode of plant communication happens underground, as revealed in a number of modern researches. Plants have a complex subterranean network of roots with associated microorganisms, including fungi and bacteria. This intricate region is called the rhizosphere. Research has shown that root exudates in the rhizosphere can mediate plant communication. Mother trees can communicate with and nourish the injured daughter trees via root exudates. Plants also help injured plants of the same or different species in the vicinity through root exudates — a form of plant altruism.

Fungi inhabiting rhizosphere — called mycorrhizae — play crucial roles in tree-to-tree subterranean communications. Via mycorrhizae, trees exchange hormones and nutrients with their neighbours (Simard, Perry *et al.* 1997). Mycorrhizae-mediated plant communication is exceedingly ancient, almost 450 million years old. A vast network of mycorrhizae connecting trees underneath the forest canopy enables these plants to exchange information. This information network resembles the planet-wide network of the internet. It is often called the “Wood-Wide Web”.

Research has revealed that mycorrhizal communication helps plants warn their neighbours about upcoming aphid attacks. The mycorrhizal network has also been shown to enable plants to detect whether they are surrounded by their relatives or outsiders — the genetic relatedness (Biedrzycki and Bais 2010). Recent research published in 2022 found that the fungi secrete ‘language’ comprises electrical impulses resembling human language (Adamatzky 2022). Scientists



Credit: The New Yorker magazine/Enzo Pères-Labourdette

Wood Wide Web: an abstract rendition

identified at least 50 spikes of electrical patterns between fungi, which they think correspond to the words of a language.

However, plant communication can also be affected by human activities. For instance, remember how wild maize plants release VOCs that attract wasps? Because of thousands of years of agriculture and plant breeding, commercial varieties of corn have lost the ability to release VOCs (Tamiru, Bruce *et al.* 2011). Scientists are now actively trying to reintroduce long-lost genes encoding for VOCs back into commercial corn varieties from wild maize so that pesticide use can be minimized.

The second strategy that scientists are currently exploring is to use sensitive, although low-yield, plants as “spies” to detect pest attacks so that they can warn the neighbouring high-yield commercial varieties through released VOCs.

Scientists eavesdropping on plant communication are expected to reveal several secret facets of the natural world dominated by low-frequency clicks and fragrances undetectable to humans. While referring this chemical communication as “language” is a form of anthropomorphism fallacy, decoding the chemical cues resembles cryptologists deciphering military cyphers or astronomers searching for signals from imaginary extraterrestrial life. Interpreting this nature of plants will continue to inspire generations of curiosity-driven scientists.

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