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# Acoustic and magnetic communication in plants

## Is it possible?

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**Over the last two decades, important insights into our understanding of plant ecology and the communicative nature of plants have not only confirmed the existence of a wide range of communication means used by plants, but most excitingly have indicated that more modalities remain to be discovered. In fact, we have recently found that seeds and seedlings of the chili plant, *Capsicum annuum*, are able to sense neighbors and identify relatives using alternative mechanisms beyond previously studied channels of plant communication. In this addendum, we offer a hypothetical mechanistic explanation as to how plants may do this by quantum-assisted magnetic and/or acoustic sensing and signaling. If proven correct, this hypothesis prompts for a re-interpretation of our current understanding of plasticity in germination and growth of plants and more generally, calls for developing a new perspective of these biological phenomena.**

The idea that plants communicate has long been a controversially debated topic, because the flow of information between plants was often thought to involve cues rather than actual signals. This distinction is important because signals are traits that evolved for a specific role in communication (see definition by Scott-Phillips[1]), while cues are only incidental features present in the environment that have not been shaped by natural selection to carry a specific meaning for intended receivers and which most researchers agree should not be considered communicative in nature.[2,3] Excitingly, important insights into our understanding of plant ecology, and specifically chemical signaling, have confirmed that plants are capable of both cue- and signal-mediated interactions,[4] processing information about their neighbors both above-[5] and belowground,[6-8] and sharing information about the resources available in their surroundings. We now know that plants can signal to each other about approaching insect attacks and even allow for pre-emptive defensive responses[4,9-11] using an extensive 'vocabulary' of chemical molecules, such as herbivore-induced volatile organic compounds (VOCs). Similarly, plants have been shown to exchange information to recognize and even prevent costly competitive interactions with relatives,[12,13] hence facilitating kin selection processes such as cooperation and altruism. And recently, we have learnt that plants are even able to exchange information to solve a problem as a group (i.e., root swarm intelligence[14,15]), just like many animal groups, from honeybees to humans. Thus over the past two decades, our perspective on plant communication has been revolutionized through an exponential increase in research effort in this area of investigation (**Fig. 1**). Such progress has been accompanied by a better appreciation of the wide diversity in communication means available to plants, and opened up the possibility that more modalities remain to be uncovered.

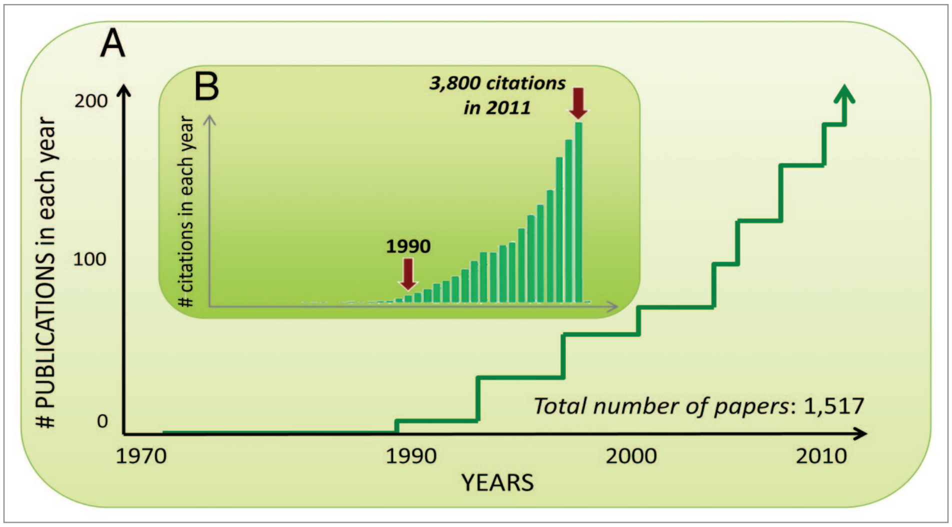


**Figure 1.** Current status of plant communication research. (A) Number of papers published in each year on the topic "Plant Communication" starting from 1970 till today (larger diagram) and (B) citation rates for the same topic over the same time period (inset diagram). Both trends are based on peer-reviewed papers only (i.e., not including books and other published material) indexed in the Web of Science.

In a recent study, we intentionally blocked above- and below-ground contact, chemical and light-mediated signals and revealed the existence of uncharted communication channels used by seeds and seedling to sense neighbors and identify relatives. Specifically, we showed that young chilli plants are able to sense their neighbors from as early as the seed stage. Furthermore as seeds grow into seedlings, they are able to discriminate among neighboring species and modify their growth patterns accordingly, without necessarily relying on known determinants, such as volatile chemicals, direct physical contact or changes in infrared light wavelengths. So what are the modalities involved for plants to perform these feats? In our recent paper, we suggested two possible explainations for the observed results, namely magnetic and/or acoustic fields, which may allow plants to recognize their neighbors. Clearly the underlying condition for any of these sensory modalities to function as a channel for the transfer of information is that plants are both able to detect such fields and, equally importantly, produce and emit them (or alter fields produced elsewhere). From a detection point of view, we have ample evidence of both magneto- and mechanoreception in plants, and the bewildering variety of plant responses to both magnetic fields (i.e., strong continuous fields as well as alternating magnetic fields)[16,17] and vibrational/sound waves.[18,19] It is not surprising that plants are endowed with mechanisms adapted to sensing and transducing such fields and vibrations; indeed like all living organisms, plants have evolved in and adapted to an environment rich in naturally occurring and fluctuating geophysical waveforms of both magnetic (e.g., extremely low frequency magnetic fields known as Schumann resonances[20]) and acoustic origin (e.g., the resonant acoustic free oscillations known as the Earth's "hum"[21]), and they are likely to have learnt to exploit the opportunities for sensory monitoring of such environment to thrive in it.[20-22] Yet, preliminary evidence of plants producing and emitting them has emerged only recently (i.e., plant magnetism;[23] plant bioacoustics[24]) and how exactly plants do so is still elusive.

The mechanisms generating both magnetic fields and acoustic waves in plants may be driven by similar biochemical processes within the cell, where nanomechanical oscillations of various components in the cytoskeleton can generate a spectrum of vibrations spanning from low kHz up to GHz[25,26] and even up to THz.[27] Specifically, Corsini et al.[23] suggested that electrical currents and time-varying electric fields, which in turn are generated by ionic flows and time varying ionic distributions, might produce plant magnetic fields. Similarly, acoustic waves may be generated as a result of mechanical vibrations of charged cell membranes and walls through alteration of their potentials[28] and/or through the activity of mechanochemical enzymes such as myosins, which use chemical energy derived from the hydrolysis of ATP in actin filaments to generate mechanical vibrations within cells.[18] Interestingly, the radiated power of numerous cells working in a collective mode (i.e., coherent excitation[26]) has been theoretically predicted to be sufficient for observable effects, leading to acoustic flows in the order of 150–200 kHz.[28] Indeed, the existence of coherent, non-localized phenomena has been previously reported in plants (e.g., quantum coherence in marine algae photosynthesis[29]) and such an approach may prove very fruitful in understanding how plants emit magnetic fields and acoustic waves. Ultimately, if such magnetic fields and mechanical vibrations can extend over large distances within the organism and also outside the organism, then there is a real possibility that plants may indeed use these means to communicate with other plants or organisms.

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