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Plant-Plant Communication – Possible mechanisms and benefits

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Abstract

Plants interact with their environment in many ways. They can emit and receive volatile organic compounds (VOC) and sound. They can reflect specific wavelengths of light and detect these light signals, reflected by other plants. They can also feel when they are touched and distinguish different types of touch. All these interactions induce different responses in the plants, helping them adapt to, and survive in their environment. This is a literary study, describing the mechanisms of the many communication ways used by plants and discussing the reasons for them to interact. Detecting messages from another plant is directly benefitable for the receiving plant but not for the emitter. Since the interactions doesn't always occur within the same species, but between plants of different species, it may seem odd that they would help each other. What could possibly be the benefit of helping a rival, competing for space, nutrients and light? A collocation of behavioural patterns indicates that the emitted cues are not aimed for other plants. The reason for the emission of these cues is to communicate with mutualists and offspring. This is indirectly benefitable to the plant itself or for its prefiltration. By eavesdropping on the cues, emitted from others, the plant can foresee future events in its environment. It can also identify its neighbours and their behaviour. By emitting cues, the plant shares some information about itself, which could be negative, but is essential. Detecting cues, emitted from others is mostly benefitable. The conclusion would be that plants aim to collect as much information about the surroundings as possible while sharing as little of it as they can.

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1 Introduction

Earlier it has been thought that the behaviours of plants have been a lot simpler than the behaviour of animals, now this theory is questioned. By eavesdropping the neighbours, a plant has the possibility to adapt its growth behaviour to the surrounding. Now there is research saying that plants can forestall forthcoming situations by communicating with its surroundings (Karban, 2008). They even display memories and act with respect to earlier experiences. Those earlier events don't even have to be their own memories, but the memories of their parents, saved in the genes (ref). Plants are comparable to animals despite they don't have any nervous system. They are living in communities that contains many different species, communicating with each other in different, very complex ways. Plants don't only interact with each other but also with other herbivores and mutualists. (Karban, 2008)

From our point of view, a plant may seem like a passive creature. When under stress, they cannot move or run from it. The fact that the plants can't change its form and move indicates that it has to have some perception about its environment. This means that plants have become experts of adapting and persisting though stress. They are organisms responding actively to water and light, constantly fighting with the changings of the surrounding environment. It needs to be able to take up signals from the surroundings in order to adapt to its neighbours. In recent years it has become clear that plants perceive their environment in an immense variety of ways. Parts of the plants have special cells, where the growth is occurring, called meristem. This gives the plant the ability to transform into different forms and adapting its phenotype to maximize the income of resources like light, water and nutrients (Leibfried et al., 2005)

There have been detected a change in herbivore-resistance among plants localized close by herbivore-exposed plants. This was later explained with a phenomenon called" talking trees" (Ueda, Kikuta and Matsuda, 2012). But are plants really communicating? How could it be favourably for them to alert their competitors? It is possible that plants are just eavesdropping to improve their chances of survival. By being aware and conscious about the surrounding events, plants can be better prepared to what is going to happen next (Baldwin *et al.*, 2006).

Plants are not communicating only with each other, but also with other organisms in different ways. One way is by releasing volatile organic compounds (VOCs) in response to their environment (Turlings and Wäckers, 2009). This system is known in both angiosperms and gymnosperms in up to 90 different plant families (Knudsen *et al.*, 2006). Plants can attract natural enemies of their attacker with the emitted volatile compounds (Mondor *et al.*, 2013) and also use a similar method for proliferation (Krug *et al.*, 2018).

They are believed to "hear" the sound of a pollinator (Veits *et al.*, 2018) or to "feel" the touch of a herbivore, landing on its leaf (Markovic *et al.*, 2016). The communication is not only performed above ground but also below ground through the roots. A whole community of plants can be connected with the help of fungi mycorrhiza where electric signals and nutrition can be transported (Gilbert and Johnson, 2017).

Volatile organic compounds don't come exclusively from plants but are also emitted in marine and terrestrial environments. But, up to 90% of the VOCs released into the air are coming from plants. They are metabolites released from the plant in to the air. The familiar smell of freshly cut grass is coming from such volatile compounds, in fact it comes from the metabolites exuded from the injured grass, going through the air, reaching our nose. (Guenther, 1995; Lerdau *et al.*, 1997).

Plants can't move or run away when they are exposed to danger. That makes it essential for them to be able to adapt or stand in defence when they are under attack. This is done by an activation of defensive genes producing secondary metabolites that are harmful or distasteful for the attacking organism. (Hilker and Meiners, 2006) A higher level of phenols has been detected in plants that are surrounded with damaged neighbour, even if they are not wounded themselves. (Ueda, Kikuta and Matsuda, 2012).

2 Demarcation

I have delimited this project to focus only on the different types of interactions between plants and other living organisms, and not including all interactions between plants and the environment. I have also focused on the reasons why plants interact with each other and what the benefits are.

This report is an overview of the different communication ways and contains a simplified description of the signalling mechanisms. I have decided not to describe those mechanisms on a cellular or molecular level. I'm not going in to details on how the different chemical compounds are synthesized, going through different metabolic pathways. Nether have I named them or the reaction mechanisms that they contain. Since the organic compounds, synthesized in plants differ with the species I decided not to go in to detail on what type of compound is used for communication. Instead, the most common signalling process was described, used in most of the plants. There are many unique types of plant interactions, different for every specie. Since it's not possible to write about all of them, the most common methods are described.

Plants interact with the environment in many ways, but I have restricted my project by defining communication as a way for the plant to detect and respond to surrounding plants. The response must come rather quickly and not take too long, in order for the phenomena to be valid as communication.

3 Method

This study is a literary study based on scientific articles and the book Biology 10.8. The articles were mainly the ways of communication that plants can have with their environment. Some of them was also literary studies, covering many different communication ways. Other was specific studies of experiments, showing the interaction between a plant and another organism, or plant. Keywords was used like, “plant-plant interaction by VOC”, “plant interaction by light” “, “plant communication”. In order to know how to search for these articles some basic knowledge about how plants interact was obligated. Then help was obtained from the tutors which contributed with some of their own research. After reading those scientific papers, it was easier to form theories and apply theories. Most of the research about plant-plant interaction is new and the articles are mostly up to date. In some cases, older background information is needed to explain the mechanism of a behaviour. This background information may be found in old articles but Instead of searching them, information was taken from the biology book, which is more up to date.

4 Theory

The importance of the interaction between plants and animals was reviled in 1970s. Among the first people to discover this was Tahvanainen and Root (Tahvanainen and Root, 1972; Richard B. Root, 1973) They discussed how the herbivore resistance of a plant is influenced by cues from other plants. Thanks to this, the method of inter-cropping became big all around the world. Even though the method has been existing for a long time, there had been no evidence that it would actually work for pest management until 1972.

Later in 1976 Atsatt and O'Dowd realized that this type of communication does not exist for all species. Some plants react to the cues from an emitter, and others don't. (Atsatt and O'Dowd, 1976) After these discoveries, plants have become a bigger subject for research. The realization about how complex these organisms are have raised the interest among many scientists.

Since the abilities of plants have been underestimated, the "talking trees" was not discovered until the 1980s and the first reports were written. This was another proof that plants do communicate. In 1983, Baldwin, with others, wrote one of the first reports about this phenomenon (Baldwin and Schultz, 1983). They made many experiments to understand the communication that occurs between plants and other organisms. The results of this research were meant to be applied in agricultural crops, making them to summon mutualistic insects during an herbivore attack. (Sharman Apt and Aguilera-Hellweg, 2002)

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5 Plant interactions

5.1 Plant interactions by VOC

When a plant is under attack, it counters by rising its defence and this can be observed in different ways. The plant start producing chemical compounds like alkaloids terpenoids, phenols, quinones and anthocyanins which can be harmful or repel the attacker. (Rani and Jyothsna, 2010) These chemicals are emitted mainly through the stomata, but also through the cell walls (Arimura, Matsui and Takabayashi, 2009)

Through specific metabolic pathways it's easy to understand that plants can alter their response depending on the input via volatile organic compounds. When the emitter plant is under attack, the plant, receiving those herbivore induced volatile organic compounds, is causing a response that rises its defence *(Figure 1)* (Arimura, Matsui and Takabayashi, 2009)

For example, this have been observed in corn pants. When the emitter plant was stressed by touching, it changed ratio of emitted volatile compounds. The plant receiving those compounds, it responded by activating genes and raising its defence which lead to that it became less attractive to aphids (Markovic et al 2019).

In another experiment, a barley plant has been exposed to the emissions from other types of barley. The emitters have a stronger resistance against aphids than the receiver. This resulted a change in the volatile compounds from the receiving plant. It was mirroring the defence of the infested plant, and became more resistant to aphids (Ninkovic and Åhman, 2009).

Plants absorb volatile organic compounds, released from other plants. Then they are re-releasing them passing the cues further. This causes the signal to spread over bigger distances, promoting a bigger amount of plants (Himanen, Blande and Holopainen, 2010). The spreading of these warning signals over whole communities of plants cause biochemical changes. These changes occur in transcription patterns in genes related to defence. The phenomenon is referred to as a prophylactic reaction towards a future attack from herbivores. (Dicke and Bruin, 2001)

Even while not exposed to danger, plants do interact through VOCs. This have been studied in onions and potatoes. Higher quantities of two types of terpenoids have been detected in the volatile emission by potato exposed to onion. When growing potatoes together with onions, the number of aphids, attacking the plants is reduced. The communication through VOCs is not always about warning signals. When plants emit VOCs they also share information about themselves. This gives them the possibility to distinguish what type of plant they have as a neighbour. (Ninkovic *et al.*, 2013).

An example of VOCs, released without provocation of any other organism, is shown in the Guarana plant. This is a plant with a strong scent which is caused by the emission of volatile compounds. Bees have a way of detecting this, which gives them the possibility to locate the flowers and get the nectar. While the bee is collecting nectar, the pollen sticks to the it and is transported to pollinate the next flower the bee is going to visit. (Krug *et al.*, 2018)

By taking up sulphur and nitrogen from the soil, the plant can synthesise terpenoids, fatty acid catabolites, aromatics and amino-acids. Most of the VOCs are deriving from these substances before they are emitted into the air. This phenomenon is called phytovolatilization. (Limmer and Burken, 2016)

Compounds that are released through the cell walls need to be modified to become more lipophilic. This is to facilitate the transport of the molecule through the membrane consisting of lipids. To make the compound lipophilic it has to go through an acylation, reduction or methylation reaction to reduce the polarity of the molecule. (Baldwin *et al.*, 2006) The vapour pressure of the molecule is very high in ambient temperatures. Also, the molecular weight is very low. This makes it easy for the volatile organic compounds to evaporate through the stroma (Pichersky, Noel and Dudareva, 2006).

Depending on the type of stimulation, different volatile organic compounds gets synthesized. For example, the plant can recognize which type of herbivore is attacking and distinguish it from other harming factor based on their methods of feeding. Some of them are chewing, others are tearing, and some herbivores insert a tube-like needle in between the cells to suck out the phloem. The plants are not only taking notice to the type of mechanical damage, but also to the chemical components in the oral secretions of the attacker. This way it can detect what type of herbivore is attacking and which toxics and volatile compounds to produce (ref). Through the released compounds from a damaged neighbour, the receiver can determine which kind of herbivore is attacking. Then it mirrors the emitter by producing the same toxins (Fürstenberg-Hägg, Zagrobelny and Bak, 2013). The VOCs are not only detected by other plants but they do also attract natural enemies of the attacking herbivores. For example, Broad beans have a mutualistic relationship with predatory insects. By increasing their production of nectar on the stem and leaves, they attract insects like arthropods which provides a defence against attacking herbivores. (Mondor *et al.*, 2013). Maize plants act in a similar way. They live in a mutualistic way with wasps. When under attack from larvae of caterpillar plants produce terpenoid volatiles to attract wasps their natural enemy (Turlings, Tumlinson and Lewis, 1990).

Interaction through VOCs between different barley plants helps them to allocate their biomass. These compounds effects where in the plant the development should occur. If barley plant has a neighbour, more of the energy would be spent on developing roots instead of stems and leaves. However, if the plant grow alone, the energy is allocated to the parts of the plant that are above ground (Ninkovic, 2003). In the same combination where emitter has limited light changes emission of VOCs. When these compounds are received by a neighbouring barley plant it respond by allocating its biomass to the shoots instead of the roots even though it has access to unliited light. (Kegge *et al.*, 2015)

Plants emit signals from the root system as well. These signals are also called volatile compounds however it might not be as easy to transport chemical molecules through the soil as it is transporting them through the air. This system of communication is made possible through symbiosis with fungi, which in return gain sugars from the plant (Read *et al.*, 2002). Mycorrhizal networks are able to cover big areas and connect multiple plant roots together, this is often referred to as the "wood-wide web". For example all the trees in a forest can possibly be connected to each other through this web of mycorrhiza (Giovannetti *et al.*, 2006).

There are different kind of fungi, some of them can connect multiple species of plants and makes it possible to transport nutrient between them. Beside the transport of nutrients, the mycorrhiza transfer warning signals between plants. For example warning signals about attacking herbivores (Barto et al., 2011).

When a plant is attacked by herbivore, it will send a signal through the mycorrhiza to another plant and the receiving plant will manage to raise its defence *(Figure 1)*. All of this happening within a timeframe of 24 hours (Gilbert and Johnson, 2017). These signals can be transported minimum for 12 cm, but there have been observed effects over 20 cm. This depends on what kind of signal it is, different substances can travel different distances. However this is a very effective way of communication where the cues can be directed and rapidly be received by the receiver plant (Johnson and Gilbert, 2015).

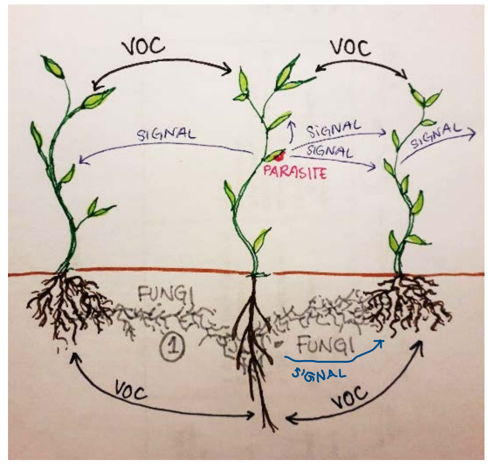

Figure 1: Plant interactions by VOC

It has been observed that plants, connected by the same root system can send cues, warning about drought. In the study one of the plants was undergoing drought stress. This resulted that the neighbouring plant close its stomata to save water. The only connection between the plants was the roots in the soil (Falik *et al.*, 2011).

There is a second way of signalling belowground which does not necessarily include volatile organic compounds. The plasma membrane of the plant is in contact with the surrounding environment, therefore its sensitive to changes in the environment and can respond to them with electric signals (Fürstenberg-Hägg, Zagrobelny and Bak, 2013). This is a very fast and effective way of communication inside and outside the plant, through the mycorrhiza. Its implemented through polarization of the membrane (Johnson and Gilbert, 2015) and has an effect on the ion flux in it. This result in action potentials, affecting the orientation, physiology and activity of the fungi. This can regulate the uptake of nutrients and the signalling between the hyphae of the fungi (Johnson and Gilbert, 2015).

5.2 Plant interactions by photomorphogenesis

The growth development that occurs in plants responding to light is called Photomorphogenesis. It's a phenomenon that allows plants to choose the direction of growth, growing against or away from light. (OpenStax, 2013). When a full spectrum of light hits the leaves, the plant absorbs most of it, converting it into energy. Since some of the colours in the light spectrum, like green, far-red and violet-blue are not fully absorbed, they get reflected instead. *(figure 2)* The reason for the plant, not to absorb all types of wavelengths is that it would get over heated and the proteins in the plant would denature (Gates *et al.*, 2008).

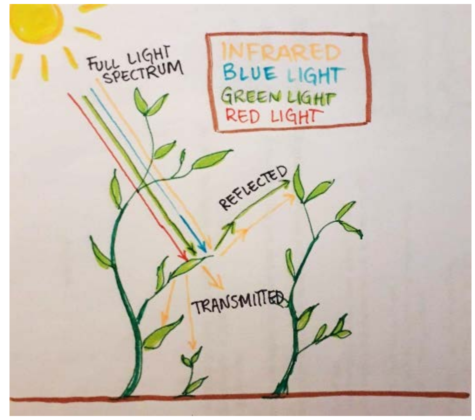

Figure 2: When light hits the leaf

Since we are not able to see far-red or violet-blue, we only see the green colour. However, plants can detect and react to both far-red and violet-blue. When light gets filtered through a leaf, the red light gets absorbed. This means that when a plant is shadowed from another plant, it receive light containing more green and far-red than visible red light. (OpenStax, 2013). With sensory photoreceptors the plant detects a difference in the incoming light. It detects not only filtered light but also reflected light from surrounding plants. Then it responds in elongation of the stem or with angling the leaves to avoid the shadow (Pierik *et al.*, 2005). There are many different photo-receptors, but the most common ones are phytochrome, cryptochrome and phytotropin (Kong and Okajima, 2016). The different photoreceptor genes are affecting each other. When one gene is activated it may repress other genes and this complex system helps the plant to respond accordingly to the surrounding environment (Casal, 2004). Plants can respond in different ways depending what specie is shading it. This could indicate that plants may be able to detect type of specie from receiving the transmitted or reflected light. It has been observed in clover, shaded by different types of grass. The results showed that depending on the type of grass, the length and biomass allocation of the clover differed (Marcuvitz and Turkington, 2000). Using phytochrome receptors, plants detect far-red light caused by the surrounding leaves (Bongers *et al.*, 2014) so it can locate and grow away from the neighbours (Novoplansky, 2009) This phenomenon is called "the shade-avoidance syndrome" and may cause the plant to spend more energy in shoot elongation or make it produce more leaves higher in upper part of the plant. But the light is not all, the plant hormone ethylene can influence these responses too. In fact, ethylene is essential for the plant to be able to compete for light. (Franklin and Whitelam, 2005) There are studies, showing that some plants can recognize relatives growing nearby. Then they adapt so they will not shadow their kin (Crepy and Casal, 2015). An example of how plants are using their photoreceptors is shown in the Monstera plant. It grows horizontally next to the ground until it reaches the shadow of a tree. *(Figure 3)* When it detects the difference in light, it changes its growth-direction to find the stem of the tree (Braam and Braam, 2004).

Figure 3: Behaviour of the Monstera Plant

5.3 Plant interactions by thigomorphogenesis

Plants are very sensitive to touch and are constantly exposed to it from the surrounding. They are able to respond to the touch stimuli in different ways depending of their type of touch. When plants response directly to touch it is called thigmomorphogenesis. When a Monstera touches the stem of a tree. The touch detectors are stimulated, and the plant changes its growth direction to climb *(Figure 3)* (Braam and Braam, 2004).

For example, it has been observed in Arabidopsis plants, exposed to a lot of wind. The plants became bushy, short and with a lot of branches. (Chehab, Eich and Braam, 2009). When a plant recognizes the touch of, for example, an herbivore, it activates defence-related genes to raise a defence. This also leads to the emission of VOCs that can be detected by surrounding plants (Braam and Braam, 2004). There are many studies showing a change in volatile compounds from touched plants (Markovic et al., 2014). The plants neighbours receiving this volatile signal mimic the behaviour of the emitter plant, raising a similar defence. For the receiver to mirror the behaviour of emitter, the receiver it had to be exposed to the volatiles for six minutes. The type of emitted compounds depends on the type of touch. They Volatiles released differ depending on for how long time the plant will be exposed to touched or held. Different factors touch the plant in different ways and it need to adapt the response. Then it will be prepared to control this specific factor in time (Markovic et al., 2016).

Plants does not like to be touched, not only by insects or by the wind, but also by other plants. For example, the tree crowns of trees growing next to each other form gaps between them. This was called “crown-shyness” *(Figure 4)* (Fish *et al.*, 2006). Yet there is no established evidence about why this phenomenon occurs.

Figure 4: "Crown Shyness"

When plants respond directly to touch it is called thigmomorphogenesis and this occurs in the Monstera plant. When a Monstera reaches the stem of a tree, it changes its growth direction *(Figure 3)*. Then the touch detectors are stimulated and the monstera changes its growth direction to climb the tree (Braam and Braam, 2004).

5.4 The bioacoustics of plants

Plants can detect soundwaves and they emit acoustic vibrations. For example, when the garden pea is undergoing drought stress it emits a signal. Then, surrounding plants close their stomata to prevent water loss. However, this message could have been delivered through other communication ways, like VOCs. It's not yet clear if the sound-emissions are the reason for the effect in surrounding plants (Gagliano, 2013). Its determined that plants emits, receives and responds to sound but purpose of this is still unknown. There are speculations that the sounds are emitted for the purpose of communication. (Gagliano, Mancuso and Robert, 2012)

When an herbivore is chewing on a plant, it emits sound which can be recognized by surrounding plants. This gives them the possibility to raise its defence before it gets attacked (Mishra, Ghosh and Bae, 2016). It has also been observed that flowers have a method of detecting the sound of pollinators and respond with production of sweeter nectar(Veits *et al.*, 2018). When a pollinator lands on a flower, the soundwaves are changing, and the plant will respond in a different way. When the flower petals receive the soundwaves, the pollen is let loose, sticking to the pollinator (Mishra, Ghosh and Bae, 2016)

Humans can hear sounds in between 20 Hz and 20 000 Hz. (Chowdhury, Lim and Bae, 2014) Plants emit ultrasonic acoustics in between 20-300 kHz but also sound waves within 10-240 Hz. During drought stress the tension in the vascularity's of the plants gets to strong and causes cavitation. When cavitation occurs, air bubbles penetrates the water canals and prevent the transport of water. This results in ultrasonic sounds and has been observed in pine trees and oak trees. (Zweifel, 2004) These sounds can reach long distances and rises the probability that plants actually use sound as a form of communication with surrounding organisms. It has been observed that music has a positive effect on the plant development. This have been tested in paddy rice. When the plant is exposed to a sound that is pure and coincides with the leaves, the plant growth is optimized. But if the sound is to intense, random or have a high frequency it can have negative effects on the plant. Sound influence the regulation of antioxidant enzymes, oxygen uptake, the protein and the RNA synthesis. It is also affecting the gene expression (Chowdhury, Lim and Bae, 2014). Studying the roots of a germinating maize-seed, exposed to sound, the tips of the roots are growing against the 220 Hz sound. The mechanism of receiving sounds in a way like this is yet to be discovered. (Gagliano, Mancuso and Robert, 2012)

The lower sound waves within 10-240 Hz is coming from the fluctuations of the stem getting thicker and from microclimatic situations in soil and air. When the fluid is transported inside the plant it also makes these low noises (Zweifel, 2004)

It has been observed that soundwaves between 70 and 120 Hz increased the seed germination of Arabidopsis plants (Uchida and Yamamoto, 2002) Seeds from chili grow faster when they are close by an fully grown fennel. This occurs even though they are totally isolated from each other and didn't had the chance to communicate in other ways than sound, or possibly magnetism (Gagliano *et al.*, 2012)

6 Discussion

The fact that plants are helping their neighbours can seem odd since it is not credible that a specie would consciously help their rival. Plants of different species are competing for nutrients, sunlight and water. Can it really be beneficial to support the competitors for the emitting plant itself? Since they have adapted to this planet a lot longer than animals, there are probably many good reasons for the system of plant cooperation and communication. Otherwise these traits would not occur due to the natural selection.

Emitting cues is energy costive and it may also reveal the plants location to enemies. The purpose would be to attract the natural enemies of their attacker. The fact that it's also warning other plants could be just a side effect because it does not directly improve the fitness of the emitter. However, it could be indirectly benefitable by counteracting with the development of herbivores. They increase the chance of survival for all plants and together, they stay stronger.

Plants may have developed methods for eves-dropping on emitted signals from others. It should be benefitable to be aware of surrounding plants. Knowing what kind of resources, the neighbour needs helps adapting to the competition. Still, by giving the neighbours as little information as possible, the plant has the chance to always be one step ahead. The possibility to predict the next coming events is a big evolutionary advantage, giving the opportunity to plan how to allocate the growth. Since plants are moving slowly and every motion is energy costive it should be benefitable avoid wasteful biomass allocation. Some species can recognize the reflection of their relatives and avoid competing with them. Instead they accept to be overshadowed even if it's not benefitable for the plant itself. However, there are evolutionary benefits with prioritizing the survival of the genes over the survival of the organism.

A question for further research would be if the age of the tree is correlated with deciding which one who will be shaded. And if so, are the plants able to detect the age of the neighbour only light signals?

By emitting signals, plants share information about themselves, giving their neighbours the possibility to determine whenever they are compatible or not. If the neighbouring plant need the same type of nutrients, they are not compatible and will keep a greater distance to each other, growing the other way and avoiding the competition. In this case, communication is benefitable for both sides. It helps the them to locate and coordinate in the nature, adapting to each other and maximize the nutrition and sunlight intake. Plants are not able to move, but they are capable to grow in directions towards profitable locations. This is a rather slow, energy costive process. Therefore, its benefitable to get cues about what direction it should grow in, before it puts energy in growing. Maybe plant seeds receive cues of other plants with similar needs and detects if the area is suitable for growing. If it's not, the seeds will not sprout.

Since the production of sound often is a side effect of other mechanisms in the plant, it doesn't require extra energy to produce. Different species produce different kinds of sounds and it travels long distances This makes it unlikely that it would not be used as a way of communication. However, so far, we don't know much about plant communication by sound.

There could be a balance between the benefits and the negative aspects of growing in a crowded environment. Getting cues and foresee future attacks is benefitable, but if the resources gets limited when they must be shared with other plants, the negative aspects may get preponderate. Maybe the plant is correlating the amount of shared information with the amount available space and nutrients? This could mean that if there are too many plants in a small area, maybe they emit less volatile compounds because the asset of nutrients and space gets more critical and of a higher importance than the help from other plants. Therefor the space factor maybe could get prioritized over the actual herbivore-defence supplied from surrounding plants. This is a theory for further examination.

The discovery of plant interactions with other species opens doors for new ideas that could be useful for us. Plants could teach us how to understand this new kind of language and how to use it. We could suddenly communicate with some species in a different way than we ever could before. Communication is the key to cooperation. With the environmental issues growing bigger we are starting to realise that we must collaborate with the nature instead of counteracting. This might be a way of doing just so. The human population have grown so much that it's impossible to produce enough food without the usage of pesticides and other unnatural methods. Maybe instead of forcing the nature to obey with deleterious methods we could communicate with it, asking it for help instead. This could be a powerful tool for protecting our crops and other valuable species. Thereby it might be an environmentally friendly option to pesticides, so we can keep up the food production with a minimal effect on the environment.

7 Conclusion

We are now realizing that plants have different behaviours that we earlier thought only were practiced by animals. There are many ways of communication between plants, but they are aiming for the same thing. Its all about collecting as much information about the surroundings as possible. While doing this, they need to share as little information about themselves as possible. This is to always be one step ahead in the competition about space, nutrients and light.

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