“Plants Are All Chemists” – The Rhizosphere

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From *The Lost Language of Plants* by Stephen Harrod Buhner, Chelsea Green Publishing, Vermont, 2002

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Once the seedling has space, breaks through the soil, and begins photosynthesis, it begins to create and release an entirely different set of chemicals into the zone around the roots – the rhizosphere. Organic and inorganic compounds: sugars such as fructose, glucose, ribose, and so on; as many as 27 different amino acids and their compounds; nucleotides; flavones; enzymes; phenolic acids; and more. These may be gaseous volatiles, water-soluble compounds, or more intractable (usually) nondiffusable compounds such as lipids (fats), mucilages, gums, and resins. (This combination of compounds from the roots is very similar to the nectar produced in the plant's flowers.) For every water-soluble compound released by a root, three to five non-water-soluble compounds and eight to ten volatiles are released. Hundreds of compounds, in thousands of combinations, can be involved through thousands of different release sites on the roots.

Plant roots, though confined in space, have an extremely large surface area. A single rye plant, for example, has more than thirteen million rootlets with a combined length of 680 miles. Each rootlet is covered with root hairs, some fourteen billion of them, with a combined length of 6,600 miles. This entire root surface releases differing amounts of chemicals at different locations, strongly regulating the local biocommunity throughout the life of the plant. These compounds promote the growth of bacteria and fungi, stimulate soil micro-flora respiration, stimulate the growth of nitrogen-fixing bacteria, and increase the numbers and mass of nitrogen nodules, their hemoglobin content, and more. But their actions are not random, nor is it random bacteria, fungi, and microflora that are affected.

Specific bacterial species, like those in the human GI tract and on human skin, have formed symbiotic associations with plant species that have lasted for millions of years. The newly germinating plant releases compounds that literally call the proper bacteria to the area where it is growing. Bacteria are so attuned to these chemicals that they respond to them even if they are present only in parts per billion. As with the human skin and GI tract, once these bacteria cover the surface of the root and fill the rhizosphere, pathogenic bacteria have little room to grow. And these plant bacteria are species specific. Taking two plants with differing symbiotic bacterial populations at random and replanting them in each other's location causes the bacterial colonies present in the soil to completely change. In a short period of time, they will match the composition before transplanting.

The compounds that plants release into the soil are in such combinations and ratios that the health of their bacterial community is maximized. The bacteria respond in kind. Some of the microorganisms, for example, provide metals from the soil, such as zinc, that the plant needs to grow. *Azotobacter* bacteria (and others) have been found to produce plant growth regulators such as cytokinins, which cause increased growth in the plants with which they are associated. *Rhizobium* bacteria form symbioses with legume plants, forming nitrogen nodules on their roots which the plants need for growth. And as with human and animal bacterial symbionts, plant bacteria release compounds that are specifically antibacterial to pathogenic bacteria that threaten the plant. These plant/bacterial populations have been interacting in this way for anywhere between 140 and 700 million years. The better the bacterial population establishes itself and the more healthy and active it is, the healthier and better plants grow.

The newly photosynthesizing plant also releases compounds that initiate the growth of revolutionary fungi (mycelia) around its roots. The compounds chemically cue specific mycelial spores to germinate, potentiate their growth, and exert powerfully attractive forces on all (already growing) symbiotic mycelia in the vicinity, calling them to the newly emerging plant. As with bacterial cues, these compounds can be strongly active, even at dilutions of parts per billion. The mycelia, which are small hairlike filaments growing throughout the upper layers of the soil, attach themselves to the surface of the seedling's root (as do some bacteria), sometimes penetrating the root body, to form a complex symbiotic relationship called mycorrhiza. This will last throughout the life of the plant. The plant, through photosynthesis, creates sugars and secondary compounds that the mycelia need for growth. The mycelia in turn provide substances the plant needs (nitrogen and phosphate uptake, for instance, can increase 7,000 percent), produce complex polysaccharides that stimulate the plant's immune functioning, and facilitate chemical communication (through its mycelial network) between all the plants in its area. Like symbiotic bacteria, the mycelia generate compounds that protect the plant from pathogenic fungi that attempt to move into the area and harm it. Plants such as Douglas fir may be in symbiosis with mycelia from as many as forty different species of fungi. Mycelial mats, connecting all the plants in a local ecosystem, will sometimes cover hundreds of acres just below the surface of the soil. From time to time, the mycelia will send up their fruiting bodies that we call mushrooms and spread billions of spores.

Everything coming into a plant through its roots and everything going out of the roots has to move through the rhizosphere. An extremely complex relationship exists between the plant and the microflora and microfauna in the rhizosphere region. Sophisticated biofeedback loops, in both directions, carry information that shapes plants' chemical production. Many of the low-molecular-weight compounds created by plants are exuded into the rhizosphere where they are transformed by rhizosphere organisms into more complex, high-molecular-weight compounds such as polymers. Only then do they become active. Many of these modified compounds combine in the soil with other plant and soil microorganism compounds to form humic acid, one of the most important elements of ecosystem regulation and soil fertility. Thus, soil health is directly dependent on the rhizosphere community and the secondary plant compounds created during photosynthesis. This rhizosphere community is also paramount in maintaining the health of the bacterial underpinnings of the life web. Plant compounds released in sophisticated complexities maintain this health, linking the rhizosphere with the sun through plant actions. The plant, as mediator, increases and decreases the kinds and amounts of phytochemicals produced in order to maintain the optimum levels of health of the soil biota. This dynamic in turn ensures its own health and maximum growth.