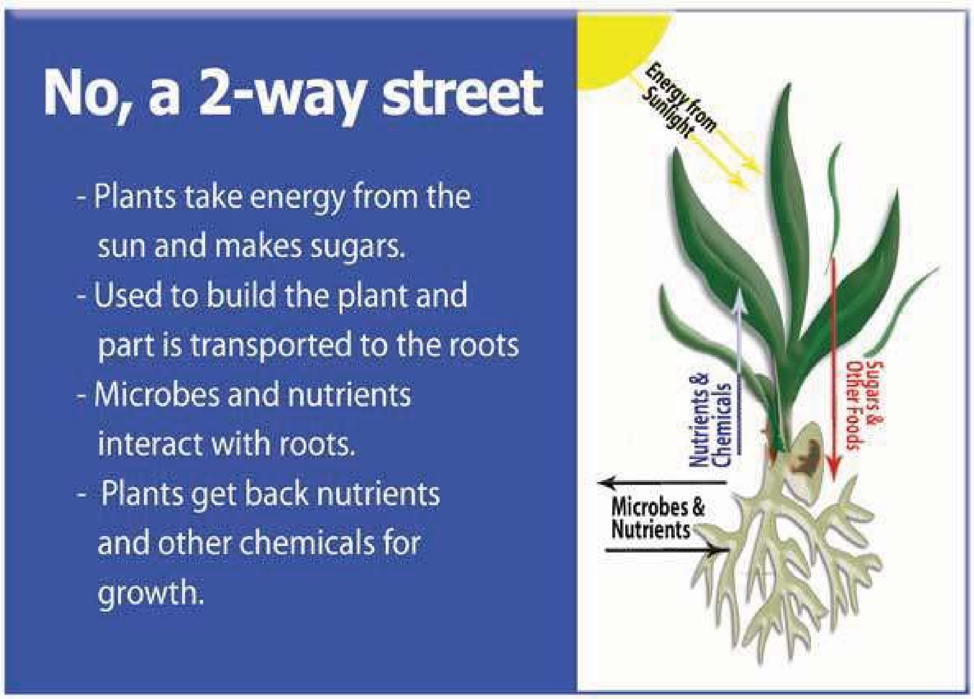
The Rhizosphere

Generally speaking, the term rhizosphere refers to the immediate area around the roots of plants. It is thought that the "rhizosphere" is about 1-2 mm from the "*rhizoplane*" (the surface of the roots). The complex plant-microbe interactions that take place in this area can have such a strong effect on plant growth and development that it is impossible for a plant nutritionist to be effective without a knowledge of this environment.

Many, in commercial agriculture, treat a plant as a "one-way street" of assimilating nutrients and water from the soil and producing a crop. This is not so, a plant is a two-way flow of energy, not only from the soil, but also into the soil from the roots, termed "*rhizodeposition*."



A PETER ALEMAN Idea

Root excrements are usually "4th in line". By this is meant that a plant will, depending on its physiological state, first pump energy (which all comes from photosynthesis) into a growing shoot, fruit or physical root hairs. Only then is the "residue" energy left for root exudes.

A practical indicator of this is the known LARGE amount of exudes a corn plant can produce; up to 9,000 lbs/acre. Corn is a C4 plant which is very efficient in light to energy conversion; therefore more energy is available for "luxury compounds."

The Complexity of the Rhizosphere

Numerous books have been written on this subject, therefore the scope of this paper will not cover all these details, but rather focus on some important aspects that can be utilized in plant fertility management.

It is thought that from 30% to 60% of the total photo-synthetically fixed carbon can be translocated to the roots and some is excreted from the roots into the surrounding soil. What is not really known is how much of this carbon is excreted from the roots and then re-assimilated. However, as we will illustrate, the carbon that is "reused" by plants can be very important to plant nutrition as it is known that many plants excrete various organic acids such as citric that solublize (chelate) micronutrients in the immediate vicinity of the roots.

Root exudes also play an important function in that they are utilized by root colonizing microbes and can be converted into various plant stimulatory compounds such as siderophores, hormones and complex amino acid and sugar molecules. The following illustrates the complexity of rhizosphere compounds and will begin the process of understanding the importance of this plant/soil function.

Sugars & Polysaccharides:

Arabinose, fructose, galactose, glucose, maltose, mannose, oligosaccharides, raffinose, rhamnose, ribose, sucrose and xylose.

Amino Acids:

α-alanine, β-alanine, γ-aminobutyric, arginine, asparagine, aspartic, cysteine, cystine, deoxymugineic, glutamine, glutamic, glycine, leucine, lysine, methionine, mugineic, ornithine, proline, serine, tryptophan and valine.

Organic Acids:

Acetic, ascorbic, benzoic, butyric, citric, ferulic, fumaric, glutaric, glycolic, malic, malonic, oxalacetic, oxalic, propionic, succinic, syringic, tartaric, valeric and vanillic.

Fatty Acids & Sterols:

Linoleic, linolenic, oleic, palmitic, stearic, campesterol, cholesterol, sitosterol & stigmasterol

Enzymes:

Amylase, invertase, peroxidase, phenolase, phosphatases, polygalacturonase, protease and numerous others.

Miscellaneous:

Auxins, vitamins, flavonones, nucleotides, glucosides, unidentified soluble proteins, reducing compounds, ethanol, inositol, myo-inositol, polypeptides, scopoletin, sorgoleone and numerous others.

The Value of "Rhizo-deposition"

Anyone at all familiar with the composition of various "bio-fertilizers" will easily recognize the value of the biocompounds produced in the rhizosphere. To be technically correct, one needs to point out that these compounds are made in 5 and possibly more ways;

1. Direct manufacture & excretion by the plant
2. Stimulation of Rhizo-Microbes to produce a compound
3. Conversion of a plant-produced compound by rhizo-microbes
4. Conversion of a soil-produced compound by rhizo-microbes
5. Production of compound by soil-microbes (humic/fulvic)

However, when it is considered that a good root system is in contact with less than 5% of the soil surface, the value of a root produced compound to plant growth is excellent, because a soil applied product would have less chance of making it to the root. Furthermore, many biocompounds that are applied in the form of bio-fertilizers are likely consumed by soil microbes even before they get to the plant root.

In consideration of Plant Growth Hormones (phytohormones), the fact that synthetic (or natural) hormones have a soil ½ life of 24-48 hours, just the value of root/microbial produced phytohormones is past understanding.

As a matter of fact, the production of phytohormones by rhizo-bacteria is likely one of the most overlooked and valuable agricultural production tools.

Another valuable form of organic chemistry produced by roots is the various chelating acids such as citric, malic and others, as well as amino acids which assist in the uptake of soil minerals.

Another valuable for of chemistry is the bio-flavonoids, which will stimulate the development of VAM to produce further biocompounds, root protecting compounds and assist in the uptake of important nutrients such as phosphorous.

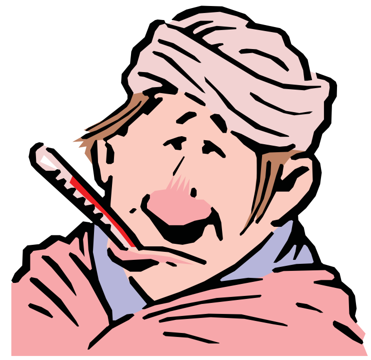
Ever hear of "money growing on trees", learn to work with the concept of stimulating the production of these valuable root exudes, and you will realize that "money" does grow on roots! Why is it that you do not own a photosynthesis meter?

Notice how closely associated root hairs and soil particles are. Did you know that due to the large amounts of mostly acidic compound excreted by roots that the pH can be 1-2 full points lower? Therefore, a pH 7.5 to 8.0 soil isn't really that bad for a healthy plant.

The microbes that live in the rhizosphere do more for the health (or sickness) of a plant than anyone is really willing to admit.

Consider – A plant is "immobile", whereas we as humans are "mobile". Our digestive system is mobile and held inside our stomach and intestines. A plant being immobile has its digestive system on the outside of its roots, in the rhizosphere. Note: how well does a healthy athlete do when he has a flu bug?

Why is it that no one works to regulate, understand and work WITH rhizo-microbiology?



Possible Roles of Different Types of Root Secretions

Role	Action
Acquisition of Nutrients Fetchers Modifiers Ectoenzymes	 Seek & Fetch (ex: phytosiderophores) Modification of the rhizosphere soil with protons and reductants (lower pH Convert unusable organic forms into usable ones (ex: phosphatases)
Acquisition of Water	Modification of the rhizosphere and soil with mucilage
Protection against physical stress	Response to high soil strength through modification of interface through lubrication and amelioration of rhizosphere soil
Protection against Pathogens	Defensive response to invasion via production of phytoalexins, microbial response or production of antibiotics
Protection against Toxic Elements	Response to a toxic nutrient such as complexation of aluminum or sequestering of sodium
Protection against Competition	Modifications of rhizosphere soil with phytoactive compounds such as alleochemicals
Establishment of Symbiotic Relationships with microbes Rhizobium Mycorrhiza (VAM) Azotobacter/Azosprillum Others	Chemotactic Reponse Nitrogen Fixation P & Mineral uptake Production of rooting agents Many important known & unknown functions

"The right set of Circumstances"

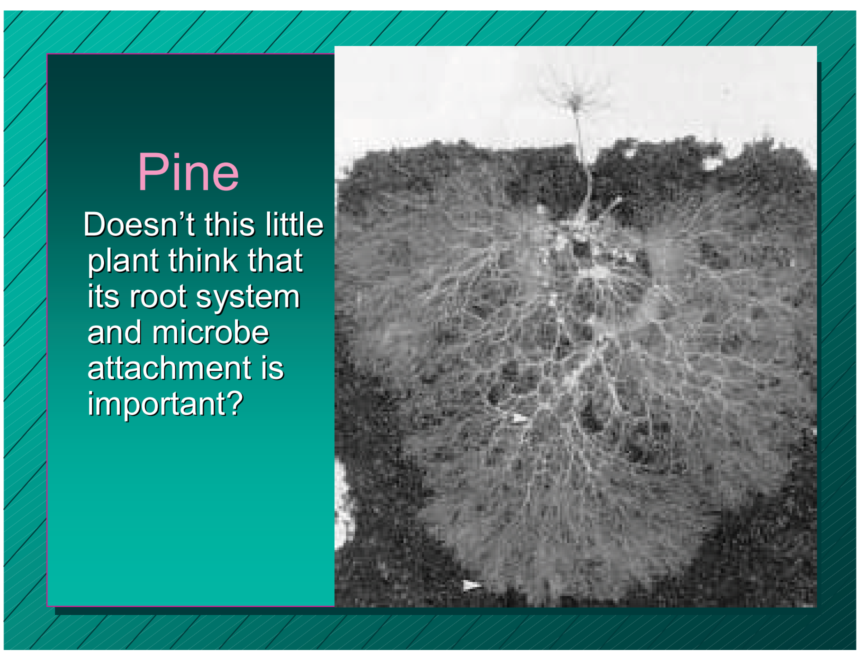
A review of scientific literature on this subject does explain why more emphasis is not placed on rhizosphere science. This is partly due to the difficulty of really producing and studying root exudes in a laboratory environment.

The difficulty of setting up a plant to function in a laboratory environment like it does under field conditions if very difficult, even when evaluating simple plant functions such as foliage growth and physical root growth. Imagine how difficult it would be to duplicate the effect of soil conditions, temperature and moisture fluctuations and the myriad of other factors that vary, even within a single field!

Consider that the complexity of organic products is vast, not only what a plant can produce, but also the thousands of different types of microbes, chemicals and organic compounds that can be produced by soil & plant microbes.

Therefore, many scholars whom have been brave enough to attack this concept are quite apologetic and this shows part of the need to separate what is practical and not. The argument here is not whether a soil scientist can identify a process and prove undoubtedly that it has a positive or negative effect on the plant, but it is a fact that we know a little about the importance of this relationship to plant health. We know that plants exude organics, support microbes and are dependent on a "healthy" soil environment. Therefore, this subject is still important to implement into an agricultural management system.

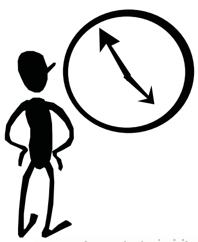
Although, we may not always be able to "invoke" the right set of circumstances to produce reproducible, scientific results; the fact still remains that root organic chemistry and microbiology can make or break a crop.



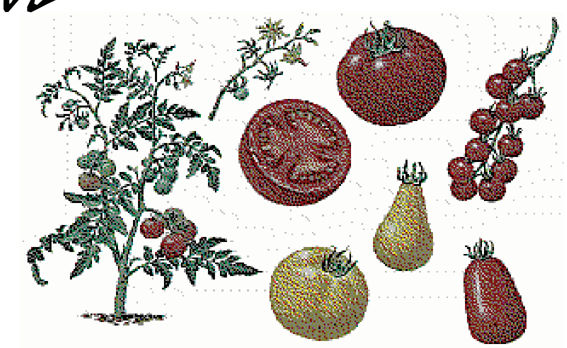
The Practical Stuff – Tools to work with

There is ample evidence that a plant can produce chemicals to support many beneficial functions. Therefore, it is important to take action to better understand and work with this concept.

Seed/Transplant Start – The best time to positively affect root microbiology is at planting. Therefore, using a "positive" microbial inoculant or foodstuff is very important, especially when planting soil conditions are uncontrollable; to dry or wet, not enough structure, too much salt, etc.



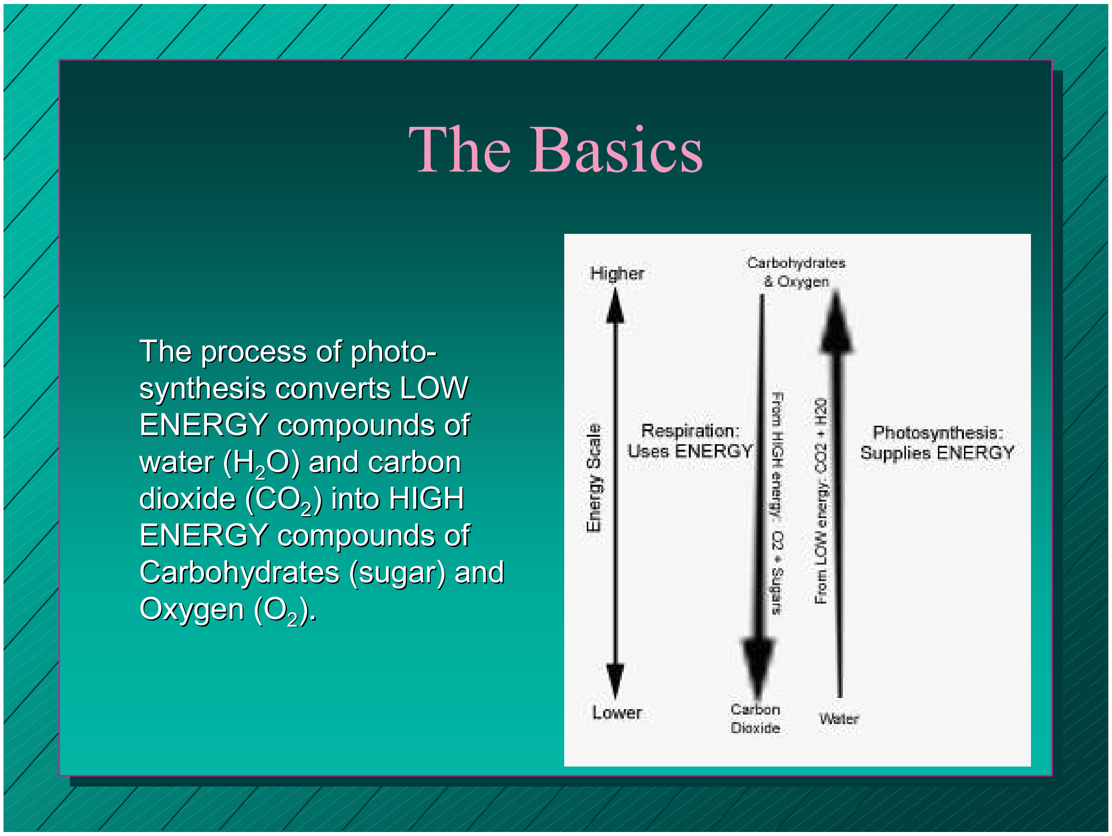
Know the Optimum Timing – It is important to know when and how the plant roots naturally and be prepared to feed and build on this process. Although every type of plant differs slightly, important timings are;



Annuals – at seeding or transplanting and during the first 20-30% of its life cycle. At full canopy, it is important to maintain some fresh root growth if the plant needs to fill fruit for a long period of time

Permanent Crops – This includes all crops such as vines, trees and berries. Early in the spring and late fall are the times when these plant naturally put on roots. Actively growing roots excreting more biosubstances and therefore a good rooting energy package is needed.

Apply nutrients & plant stimulants for Root Development!



Fertilizer – Feed – Foliar for PHOTOSYNTHESIS

Further understanding the function of energy verses root exudes can partially explain why a simple foliar can sometimes make such a large unexplainable difference in crop development. The concept of photosynthesis & ENERGY is so important that we have produced a specific publication on the subject. This is to illustrate that a foliar application that increases chlorophyll, which in turn increases the AMOUNT of the ENERGY produced in the solar collector (the leaf) that leads to more energy (sugar) for organic chemical building.

Growing a plant can be easily summarized as follows:

The Leaf – A solar collector (converts light to sugar – energy)

The Stem – A pipeline for energy transport (moves the energy)

The Fruit – The storage tank for the energy (collects energy for sale)

The roots – A foundation, anchor & toolkit (nutrients, water, etc.)

Get out the meter & tune the solar collector for optimum chlorophyll production!

Create a Good Soil Foundation

No fertility system works in a tight, anaerobic soil condition. For this reason we have produced publications on soil colloids and the importance of clay, calcium and humus for soil structure.

Proper drainage, water holding capacity, air structure and nutrient balance are likely the most important yield limiting factors. Soil structure starts with;

- ✓ **understanding the clay concept**
- ✓ **reading a soil test and working towards proper calcium balance**
- ✓ **working towards organic matter rotation and humus formation**
- ✓ **creating soil porosity with tillage & surfactants if needed**
- ✓ **balancing important nutrients such as N, K, Ca & Mg**
- ✓ **dealing with "problems" such as high pH, low pH and high salts**

.... and more!

A well aerated soil with proper organic matter cycling with result in better balances of "positive" microbiology. Most soils contain this biology, its just waiting for the proper management.

Basic Program:

1. Soil Test – Get a good soil test and put out a balanced macro & micro nutrient program. Look past "volume" and work towards applying the right forms of nutrient in the right way at the right timing.
2. Start the Plant – Early application of the proper biosubstances for rooting and quick development is essential. Many races are won with a good start. Plan a starter fertilizer with rooting substances and a good package of root promoting microbiology if needed.
3. Don't Over-N – Most crops are made "weak" by low K, Ca, B & Mg and excess nitrogen. The more you push growth with N, the more you must feed K, Ca, B and Mg.
4. Don't Over water – Water is the most critical element, but due to high-N plants, poor root microbiology and nutrient availability, most crops are weak and over irrigated to compensate. Know this problem and deal with it in some way.
5. FEED Photosynthesis – Foliar do pay, but if you are only foliar feeding lacking nutrients (trace elements) you have already lost the battle. Plants take up nutrients through the roots, put nutrients in the soil whenever possible. Foliar feed to balance the leaf and create the most efficient solar

panel. An overlooked system of crop improvement is the application of amino acids, sugars and various other biocompounds as a foliar feed to increase the efficiency of the leaf. If you don't have a good penetrating surfactant, find another job!

6. **Understand Disease Pressure** – There is no doubt that disease is one of the most yield and quality limiting factors also. The first golden rule to remember is that agriculture is not always a "perfect" system. Many soils were never meant to produce the types of plants and the yields that we produce on a regular basis. KNOW every major disease, its METHOD of function and its PURPOSE for being there. Many "biofertilizers experts" know little about good microbes and nothing about the "bad".
7. **Learn Phytohormones** – These compounds are your "directors", they can be used to further tune the plant into maximum production.

There are many other factors, but these are some of the most basic parts of a complete fertility system to work with and understand.