SOIL HEALTH TECH BULLETIN I

FACT SHEET

Soil Health is on every one's mind these days and most people are looking towards more sustainable agriculture with a reduction in the use of synthetic fertilizers and pesticides. Soil Health is a combination of biological, chemical and physical properties that combined determine the Soil Quality but more importantly of recent termed Soil Health. These two terms will continue to overlap as we look at soil, not just as a lifeless inert growing medium but more as a living, dynamic and continually changing ecological environment. Healthy soils are all about the interaction between plants and soil microorganisms that complete this cycle of life and the activities going on in the top 15 cm of soil that supports most of the life on this plant. This is less understood than the vast universe that we are a part of.

Researchers today are looking at the human biome and what is happening with the microbial population in the human gut and how we function. Our research on soil health is finding that the plant rhizosphere is much like the human gut or I relate it to the gut of the plant and the interaction of the microbes in the rhizosphere is much like the relationship in the human gut. Research at A&L on soil health is taking on an ecological approach where we are studying the relationship between plant and the soil biome and the signaling that takes place here.

The plant returns 40-60% of the photosynthates that it produces to the ryzosphere. This is a tremendous amount of energy that goes to feeding the organisms in the rhizosphere and culturing the soil biome. Plants use these many compounds that are produced to signal organisms and in the proper system encourage a relationship with a very select group of bacteria (endophytes) that help the plant grow, produce the nutracueticals that are the plant, fight disease and insects, and produce the crops grow.

A&L Biologicals, since its beginning in 2010, has focused on identifying and understanding the soil microbiological, plant relationship and how it influences crop production. The research was directed to "what is the identity of the microbes that populate the rhizosphere and host, how does the host select or signal for them, what is the unique characteristics of each of the microbes, and how do we create a healthy environment to assist the host in maintaining the ideal equilibrium amongst these populations.

SOIL HEALTH AND SOIL CHEMISTRY

The primary component in this assessment is the Soil Health chemical analysis that measures the general fertility of the soil which A&L's research shows has direct correlation to the plants ability to provide the necessary nutrients (carbon) that attracts and supports the organisms that benefit and support plant growth. Included in this test is the Solvita 1-day test that measures soil respiration which measures the carbon dioxide being released by the soil microbes over a 24 hour period. Also, it provides a new analysis which is "Reactive Carbon" that research has also shown to be a more responsive test that signals the deterioration of physical, chemical, and biological properties. The soil factors that may cause a decline in "Reactive Carbon" include reduced aggregate stability, increased bulk density, reduced water infiltration and water holding capacity, microbial activity, and nutrient availability.

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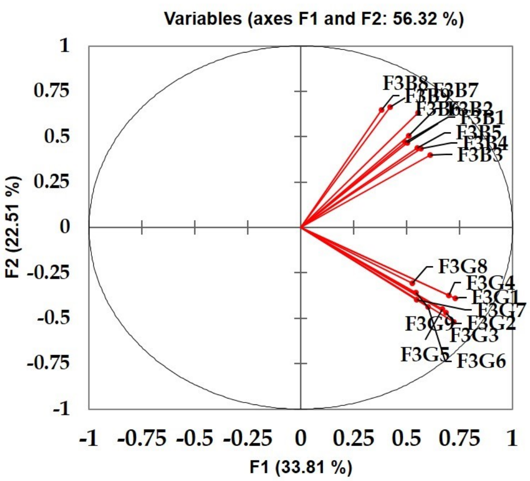
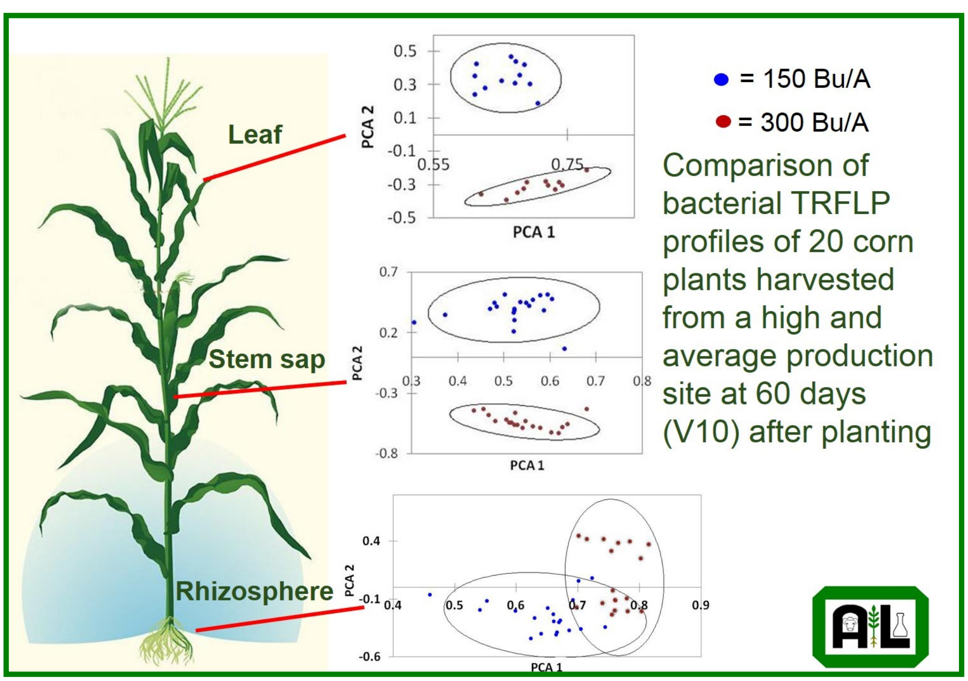
SOIL HEALTH TECH BULLETIN I

Dr. Lazarovits and I have worked together for a number of years before he joined my firm and we always agreed to disagree as he was a plant pathologist and I was a plant physiologist. My belief is that plant nutrition has a lot to do with disease and insect infestation in plants as well as growth Dr. Lazarovits has a different point of view. However in the very early stages of this research we did notice a very close correlation to soil pH and soil health and the diversity and selection of endophytes in the plant.

Dr. Lazarovits developed a technology known as **TRFLP** to analyze the population of the endophytes in the soil but and in the plant.



This analysis was done on the rhizosphere and various areas of the plant and what was noticed was in the bulk soil there was a lot of diversity but as the plant in the healthy soil grew it started to select the communities of endophytes that it required for optimum growth. The plant from the poor yielding field took up the diverse population and did not differentiate. The question raised was why the plant from the high yielding field being selective and what was the cause?



SOIL HEALTH TECH BULLETIN I

My hypothesis was that something in the soil was causing this and the overall nutrition of the plant from the soil chemistry was allowing the plant to produce a carbon source that was signaling to the micro-organisms and providing the necessary food source to nurture these endophytes.

Statistical analysis was performed on the soils chemistry to determine if there was a direct correlation to what was happening.

Correlation analysis of the contibution of different factors to the Microbial community							
	Parameter	1	2	3	4	5	6
Sl No	Microbial Population	Factors correlating to Total CFU	Factors correlating with the Gram Positive Bacteria	Factors correlating with the Pseudomonas Population	Factors correlating with the Rhizobium Population	Factors correlating with Nitrogen fixers Population-CFU-JNFb/LGI	Factors correlating with CFU of fungal communities
	Direct Yield parametes						
1	Cob length (cm)		-0.436				
2	Diameter @ centre (cm)		-0.389				
3	Kernels in middle cross sectioned cob					0.595	0.398
4	Total Plant Biomass					0.397	0.424
	Microbial Parameters						
5	Total Bacterial CFU's				0.548	0.479	
6	CFU of Pseudomonas		0.855				
7	CFU of Gram +ve Bacterial community						0.466
	Soil Parameters						
8	Organic Matter					-0.473	
9	Bulk-GFI		-0.407				
10	Magnesium (Mg) ppm (B)	0.502			0.609	0.449	
11	Calcium (Ca) ppm (B)		0.706	0.66			0.469
12	Sodium (Na) ppm	0.566		0.4	0.53		
13	pH		0.428				
14	CEC meq/100g (B)		0.717	0.695			0.438
15	% K		-0.467				
16	% Mg (B)				0.478	0.459	
17	% Ca					-0.394	
18	Boron (B) ppm	0.506		0.517	0.474		
19	Soluble salts ms/cm		0.564	0.559			
20	K/Mg Ratio (B)				-0.534		
21	ENR(Estimated N release) (B)					-0.436	
22	NH4N ppm					0.469	
23	Chloride (Cl) ppm					0.394 (b)	0.441
	Plant Parameters						
24	Nitrogen (%)	0.409					
25	Phosphorus (%)		-0.413				
26	Potassium (%)			-0.47	-0.464		
27	Magnesium (%)	0.397					
28	Manganese (ppm)	0.457					
29	Aluminum (ppm)					-0.467	-0.4
30	N/S				0.498		
31	P/Zn					0.42	
32	N/K	0.63					
33	K/Mg	-0.398					
34	K/Mn						0.396
	Number of Factors correlating	8	10	6	8	11	8

SOIL HEALTH TECH BULLETIN I

Statistical analysis was performed on the soils chemistry to determine if there was a direct correlation to what was happening.

In previous research that A&L had done significant yield increases had a direct correlation to K:Mg ratio and also in further work on controlling scab in potato. K:Mg ratio in the correct balance has a big influence on any living organisms ability to produce ATP which is a major requirement in the function of all living organisms so it only makes sense that this would be likely in the selection of endophytes and overall yield of the plants.
In summary of many of the beneficial endophytes that we isolated we saw very significant correlation to the selection of endophytes and to the degree that they where taken up by the plant.

List of Factors showed significant direct correlation to the yield

Fields with high total CFU	
GFI (B & R)	0.678
% K	0.774
Nitrate Nitrogen	0.488
Boron	0.615
Ca/B	-0.672
P- Bray-P1 & Bicarb	0.751
K/Mg Ratio	0.836

high *Pseudomonas*	
GFI (B &R soil)	0.950
Calcium (Ca)	-0.986
% K	0.909
Saturation (%) P	0.775
pH	-0.822
CEC meq/100g	-0.856

All Fields with high *Rhizobium*	
GFI(B & R)	0.686
% K	0.641
Nitrate Nitrogen (B&R)	0.767
pH	-0.629
Soluble salts ms/cm	0.705
K/Mg Ratio	0.623

High gram positives population	
GFI Rhizosphere	0.698
Nitrate Nitrogen	0.631
% K	0.704
K/Mg Ratio	0.567

Summary:
Soil factors significantly influenced in balancing the microbial population thereby the yield

Rank	Factors
1	GFI
2	% K
3	K/Mg Ratio
4	Nitrate Nitrogen
5	pH
6	CEC meq/100g
7	Saturation (%) P
8	Soluble salts ms/cm
9	Calcium (Ca)

Our research show us that the sustainable approach that is presently in practice presently is not the answer in that we need to feed the plant a very rich diet of balanced nutrients in order for it to produce the proper compounds to signal the specific organisms that will assist it in development.

One example of the interaction between plant and microorganism is that of rhizobia a beneficial organism that fixes nitrogen in legumes. The plant requires adequate levels of boron and potassium in order to produce the compounds that signal to the rhizobia to infect that plant. The plant also requires adequate levels of boron in order for it to produce the proper internal signals so that it recognizes rhizobia as a good bacteria and not an invader. In situations of low boron the legume cannot identify rhizobia as a good bacteria and it actually kills it. (Belanos et al 1996,2001;Redondo-Nieto et al, 2007;Reguera et al 2009). This is only an example of many signals that plants produce internally and externally that require the proper carbon developed by the plant.

The complexity of interactions between plant and microbial communities' increases with microbial diversity, the resulting diversity and complexity may act as a buffer between the positive or negative effects of each microbial species on the plant growth, resulting in a net zero effect. A balanced soil with the right combination of nutrients to

SOIL HEALTH TECH BULLETIN I

supply the plant will develop a more efficient plant producing the proper carbon source in the right amounts to sustain the right microbial population. Our research has shows that in a poor nutrient system the plant cannot produce enough of the right carbon to select the unique population it requires. When this happens the population in the rhizosphere is very diverse and there is too much competition for the carbon source and the beneficials cannot compete. With the proper nutrient balance the plant produces the proper carbon source to select the right group of organisms and very early in the plants development the endophytes that are selected for become less diverse and more compatible.

Our research identified the relationship between nutrient levels in the rhizosphere and the selection of specific populations of endophytes that the plant takes up to assist it in growth and development.

Now that we have identified some of these relationships it is our goal to produce a soil and plant health test that can rate the health of the soil and its ability to support both plant growth and soil biome. In the next few years we will develop a management tool for growers that rates their soils in their ability to produce healthy crops with the least amount of environmental impact. Healthy soils require less pesticides too control weeds, disease and insects as that plant provides the necessary carbon source to nurture the proper soil microbes to manage the soil environment.

One of these specific organisms (rhizobium) produces exopolysaccharides which improves root dry mass, root and shoot growth and fertilizer use efficiency through better control of water and nutrient uptake by improving the root adhering to soil which is created by increased soil aggregation. These organisms plus pseudomonas and bacillus also produce various antibiotics that help fight both soil born and plant disease.
We plan on developing a suite of soil test that deal with a number of soil health conditions to help the grower manage the crop and move toward a more sustainable system of plant health and development of soil biome stability and health.

In our research, we are also looking at the effect of soil applied pesticides and their impact on soil microbes. We have collected and analyzed many soil samples from the plots we have worked on creating a data base of information on back ground residual pesticides that is in the soils we are selecting. The aim of this work is to establish what pesticides have the biggest impact on the soil biota. This will provide valuable information to the grower on the proper use and rotation of products to reduce the detrimental impact on the soil biome. Pesticides are a necessary tool in production agriculture but if we understand the dynamics of the relationship to soil health we can do a better job managing their impact.