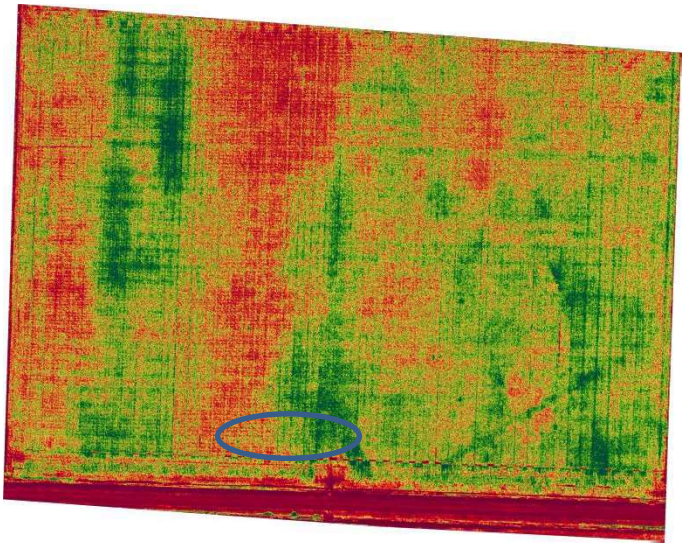
Soil Health as it Relates to Yield – Year 5 Final Report

Purpose: To compare A & L Canada Laboratories' new soil health analysis (Vitellus) and other soil health measures to yield and plant performance.

Methods: In the first three years of the project up to seven co-operators from each county (Lambton, Kent, Essex) were to provide corn fields to be sampled. Fewer locations were possible in the last two years based on timing and budget constraints. The cooperators had to have a combine yield monitor and be able to generate yield maps for the field. Field location information was collected and sent to Warriner Ag in years 1 and 2 (in 2020 it was sent to AGRIS). The location information is used to create field boundary maps. The maps are used by AGRIS Co-operative to have aerial imagery flown using Normalized Difference Vegetation Index (NDVI) technology for each field, see figure 1. This took place once the corn had reached the V10 stage (10 leaf collars) and no later than the R1 growth stage (silking – silks emerging from husks at tip of ear). The imagery was used to identify areas of the field that are healthy and areas that are stressed.

Figure 1. Normalized Difference Vegetation Index (NDVI) Map showing where the samples were taken from (green areas represent healthy areas and red indicates stressed areas).



One stressed area and one healthy area were sampled in each field. At each sampling point 5 corn root balls were dug up and individually bagged and tagged, see figure 2. The letters A and B were randomly assigned to the healthy and stressed samples. The growth stage of each plant, sample date and GPS coordinates were recorded. Twenty soil cores (six inch depth) were taken for aggregate stability analysis (note change in procedure in 2019). The soil and root balls were sent to A & L Laboratories within a day or two of sampling. Soil was sampled from the root ball and analyzed for fertility. Soil from the root ball was analyzed using the A & L Laboratories soil health test Vitellus and a portion of the root from each root ball was analyzed to assess the microbial community. The aggregate stability analysis was completed in Dr. Laura Van Eerd's lab

at University of Guelph Ridgetown Campus using the automated wet sieving method by an Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) summer student (2020 - 2022 the samples were sent to SGS Labs for the aggregate stability analysis).

Figure 2. The root balls are tagged and ready to be bagged and sent to the lab.

Just prior to harvest, corn cobs were harvested from two rows (1/1000 of an acre per row) adjacent to each of the sample points in each field. The samples were shelled and hand harvest yields were calculated for each sample point. Each co-operator was to harvest their field using a combine equipped with a GIS capable yield monitor. Yield data for an area 30' long by the width of the combine for each sample point was to be used to compare yield to the soil health and root microbial analysis. Due to a number of inconsistencies with GPS coordinates, yield monitor malfunctions and in 2018 abandoned fields due to DON; the hand yields proved to be a more reliable data set during the project.

Figure 3. Yield was hand harvested (2 rows 1/1000of an acre per row)

Basic crop information was collected as well as soil management history for each field. This provides background on management practices which then can be used to understand if any specific BMP's along with any soil health test characteristics lead to higher yields and healthier soils.

Results:

2018

2018 was a challenging year to start the project with a wet planting season, dry mid season and a wet harvest. DON further complicated the harvest and resulted in the loss of some harvest data. 17 fields were sampled and analyzed for the Vitellus suite of tests

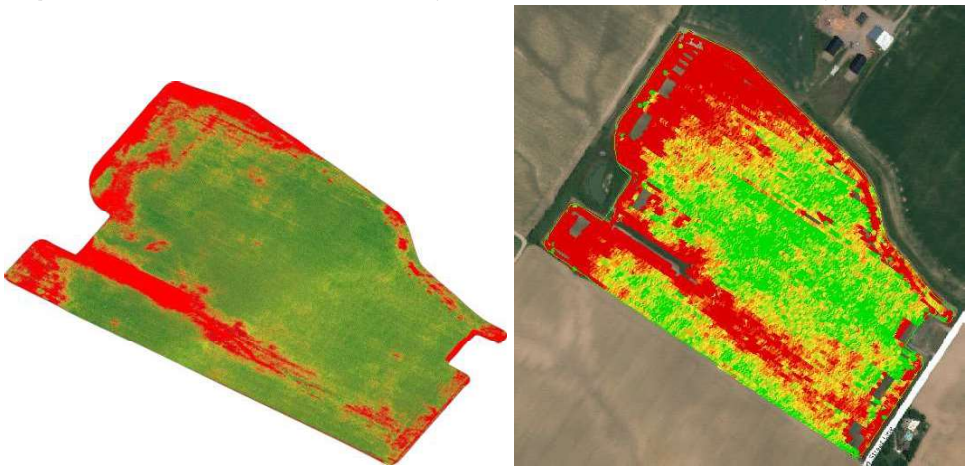
and also aggregate stability. The full data set was further analyzed in Dr. Laura Van Eerd's lab for significance using principal component analysis. With the bulk soil there was no clear separation detected between healthy and stressed zones. There was a trend towards greater yield, organic matter and P in healthy than stressed zones. However in the rhizosphere, soil Zn and microbial active C were greater in the healthy than stressed samples while Fe, Al, % saturation Al, nitrate-N and water extractable inorganic N were greater in the stressed than healthy areas. This of course is data from only one year.

Site selection (i.e. healthy versus stressed and site within the field e.g. distance from headland to allow for yield monitor accuracy), sample timing, site identification/documentation and a project protocol document were identified as areas that needed refinement for 2019. It was also suggested that the bulk soil samples did not need to be collected as the fertility samples could be taken from the soil associated with the root balls.

Most of the fields had fairly similar hand yields between the sites A and B selected for this study. On seven out of the seventeen fields studied, the differences in yield between the sites A and B were less than 10 bu/ac; on five fields the differences in yields between sites A and B were between 10 and 20 bu/ac; and in only four fields were those differences more than 20 bu/ac. One of the fields was harvested before hand yields could be taken.

The fall proved to be challenging as well. Two of the fields were not combined due to high levels of DON. Some of the other fields were later being harvested (into January) due to wet field conditions. Other challenges included data gaps in yield maps where the samples had been taken. Figure 4 shows some fairly good similarities between the NDVI map and the combine yield map.

Figure 4. NDVI map flown on July 18, 2018 on the left and the yield map on the right.



The soil around the roots was analyzed using the A & L soil health test. Overall eight of the fields showed higher numbers for several soil health indicators where the samples were taken from healthy areas.

Table 1 below lists several soil health indicators comparing healthy areas to stressed areas. Organic matter, Solvita CO2-C, reactive carbon, % microbial active carbon, NRCS soil health calculation and biological soil quality appear to be valid soil health indicators with slightly half of the "healthy" areas displaying higher values than the "stressed" areas.

Table 1. Soil Health Indicators of Healthy Areas Compared to Stressed Areas (2018)

	Healthy Compared to Stressed Areas		
Indicator	**% Higher**	**% Same**	**% Lower**
General Fertility Index	41	18	41
Organic Matter	53	24	24
Solvita CO2-C	59	0	41
Reactive Carbon	59	18	24
Soil Health Index	35	47	18
% Microbial Active Carbon	59	12	29
NRCS Soil Health Calculation	53	12	35
Biological Soil Quality	53	18	29
Wet Aggregate Stability	35	12	53

See notes on Indicators at the end of report for more information on individual indicators.

The project partners met to review the protocol and 2018 experiences, particularly around site selection within a field. This discussion resulted in some revisions to site selection and sample collection.

2019

2019 was the second year of this project. 18 fields were volunteered by soil and crop members for the project. Locations ranged from as far west as Harrow to just outside Arkona in the north end of Lambton county. Extended wet conditions during planting meant that several fields that were supposed to be part of the project were missed and other locations substituted. Most fields were clay, clay loam or loam soils with a few sandy loams. Once again, it was a challenging year with delayed planting due to wet conditions, followed by dry conditions mid-season and a return to wet conditions during harvest.

The delayed and drawn out planting made it difficult to know when the fields would be ready to be flown for the NDVI. In some fields the NDVI maps did not show a lot of differences in the field making it difficult to choose healthy and stressed spots in the field. Where available, previous yield maps were consulted to select sample areas. The NDVI imagery is a snapshot in time, showing crop condition at that time. In 2019 there were a couple locations where the good and stressed sites had switched by harvest time. Early good growing conditions set the crop up to look good but later weather stresses contributed to a lower yield.

Figure 5 All 17 sites were hand harvested. The late start to the planting season meant a later harvest with some project fields not being combined until winter. Stalk strength was a significant issue in one location.

Table 2 below lists several soil health indicators comparing healthy areas to stressed areas. For the 2019 sites general fertility index, Solvita, reactive carbon, microbial acive carbon and wet aggregate stability appear to be valid soil health indicators with more than half of the “healthy” areas displaying higher values than the “stressed” areas.

Table 2. Soil Health Indicators of Healthy Areas Compared to Stressed Areas (2019)

	Healthy Compared to Stressed Areas		
Indicator	**% Higher**	**% Same**	**% Lower**
General Fertility Index	61.1	5.6	33.3
Organic Matter	44.4	5.6	50
Solvita CO2-C	52.9	5.9	41.2
Reactive Carbon	61.1	0	41.2
Soil Health Index	55.6	16.7	27.8
% Microbial Active Carbon	58.8	0	41.2
NRCS Soil Health Calculation	50	11.1	38.9
Biological Soil Quality	47.1	29.4	23.5
Wet Aggregate Stability	77.8	0	22.2
Yield	61.1	5.6	33.3

2020

In the third year of the project, 14 fields were sampled from across the St Clair region from Harrow to Watford and across a variety of soil types. The field number was reduced for a number of reasons ranging from previous cooperators having a shift in corn acreage and yield monitor issues. The weather across the region cooperated with only short dry conditions in late summer. Access to the University lab was limited (due to

Covid) and a lack of student support, consequently the aggregate stability samples were sent to SGS Labs in Guelph for analysis where soil texture analysis was also completed.

Based on the last two years experience, site selection relied heavily on soil maps, historical yield maps where available and the NDVI imagery supplied by AGRIS. Site selection appeared to be more consistent in 2020 in terms of yield aligning with the good/stressed areas selected from the NDVI maps. Based on the soil maps (accessed in field through Ag Maps http://www.omafra.gov.on.ca/english/landuse/gis/portal.htm) all but 1 field was consistent in soil series between the two sampling areas. From the soil textural analysis there appears to be a bit more difference. Topsoil depth was estimated at each sampling area using a soil probe. There was only one location where the "stressed" had a deeper topsoil layer than the good. On average across the 14 sites the "good" sites had 1.1 inches greater topsoil depth.
Corn yields across the sites ranged from 146 to 252 bu/acre (hand yields). Only one location had a slightly higher yield in the "stressed" area; the average difference was 35.7 bu/acre (range -3 to >90).

Table 3.Yield and physical soil differences

Site	Soil texture	Difference in topsoil depth	Yield difference bu/acre
3	Loam vs clay loam	2	19
6	Sandy loam vs loam	0	50
10	Silty clay loam vs silt loam	3	21
12	Loam vs sandy loam	0	28
13	Silty clay vs silty clay loam	2	70

Table 4 below lists several soil health indicators comparing healthy areas to stressed areas. For the 2020 sites general fertility index, organic matter, reactive carbon, Soil Health Index, NRCS soil health calculation and wet aggregate stability appear to be valid soil health indicators with more than half of the "healthy" areas displaying higher values than the "stressed" areas.

Table 4. Soil Health Indicators of Healthy Areas Compared to Stressed Areas (2020)

	Healthy Compared to Stressed Areas		
Indicator	**% Higher**	**% Same**	**% Lower**
General Fertility Index	71.4	7.1	21.4
Organic Matter	57.1	21.4	21.4
Solvita CO2-C	50	0	50
Reactive Carbon	64.3	0	35.7
Soil Health Index	71.4	7.1	21.4
% Microbial Active Carbon	50	0	50
NRCS Soil Health Calculation	57.1	7.1	35.7
Biological Soil Quality	28.6	50	21.4
Wet Aggregate Stability	71.4	7.1	21.4

2021

Three sites were sampled for the A and L Labs Vitellus package as in previous years. Again, site selection relied heavily on soil maps and historical yield maps. The renewed funding also allowed an opportunity to examine portions of the Soil Health Assessment

and Plan (SHAP) package of soil health tests. This was applied to the three sites plus a further two locations.

In particular VESS (Visual Evaluation of Soil Structure) was used to assess soil condition at the sampling sites. Generally VESS scores were slightly higher in the higher producing sites although surface soil conditions were very similar. The impact on yield may be connected with better emergence and slightly higher plant populations in the sites with better soil structure.

Figure 6 For more background on VESS see https://fieldcropnews.com/2022/08/visual-evaluation-of-soil-structure/

The Vitellus package of tests showed higher yields corresponded with higher soil organic matter and higher reactive carbon while the General Fertility Index, Soil health Index and NRCS Soil health calculation were not as consistent.

The analysis of the microbial communities appears to show some differences, not so much with the bacterial communities but there are some differences with fungal communities. Often the fungal communities are higher in the higher producing sites but are not significantly higher. It is suspected that some of the differences are due to the pH differences among sites.

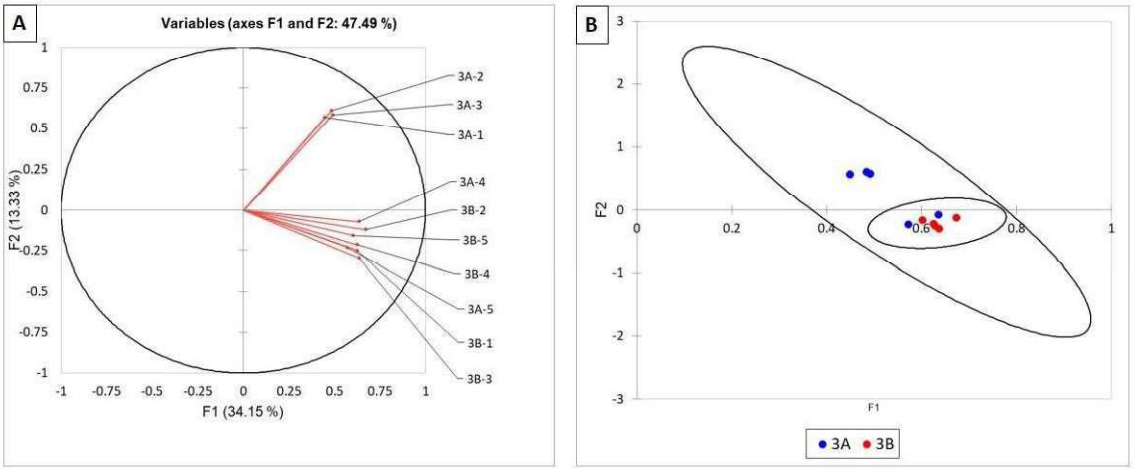


Figure 7 Statistical analysis of TRFLP of the bacterial communities in corn roots of field 3. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B)

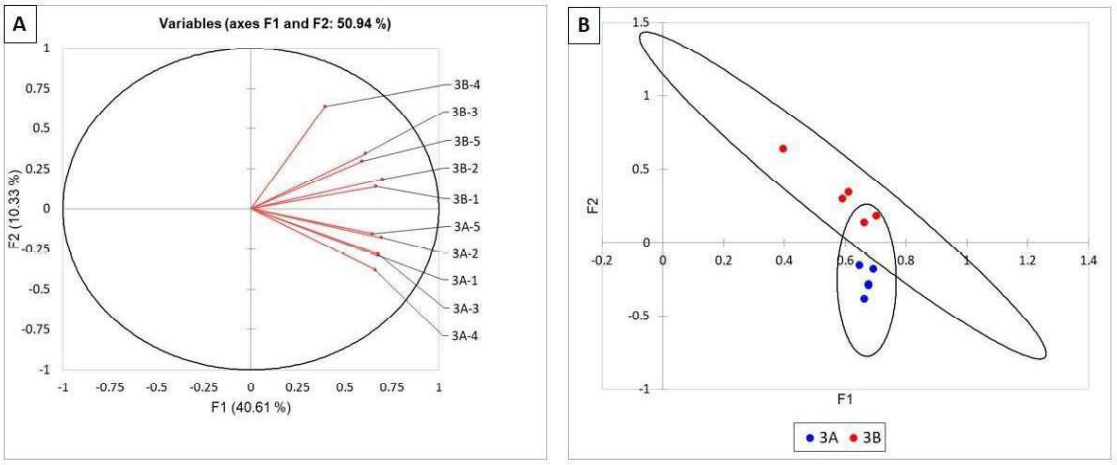


Figure 8 Statistical analysis of TRFLP of the fungal communities in corn roots of field 3. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

2022

Eight sites were sampled for the A and L Labs Vitellus package similar to previous years. Again, site selection relied heavily on soil maps and historical yield maps and successfully identified highly productive versus less productive sites across all the fields studied. Similar to 2021 elements of SHAP were applied to the same sites with samples sent to the lab for textural analysis, reactive carbon, respiration, potentially mineralizable nitrogen and aggregate stability. Many of the sites were extremely dry at the initial soil sampling and some remained so until close to harvest. Again most of the sites

suggested microbial population differences in line with the yields but did not show significant differences in terms of bacterial and fungal communities.

Table 5 2022 Summary of Results

Site	Yield	Differences in bu/ac (field with higher yield)	GFI	SHI
1A	274.2	11.1(B)	70	36.4
1B	285.3		82.6	42.4
2A	196.7	60.8(A)	63.2	33.8
2B	135.9		66	34.8
3A	165.4	12.7(A)	57.8	31.6
3B	152.7		56.4	30.4
4A	136.3	43(A)	72.6	39.2
4B	93.3		67.6	37.4
5A	N/A		67.4	37.2
5B	N/A		64	35.6
6A	205.8	22.2(A)	76	40.6
6B	183.6		61.4	32.2
8A	87.8	52.7(B)	55.4	29.4
8B	140.5		58.2	31.8
9A	187.7	6.1(B)	71.4	36.4
9B	193.8		79.6	40.8

Summary:

Each year of this project experienced some challenges from disease to weather to equipment malfunctions, a pandemic and a short break in funding.

As the conclusion in the A and L report shows, the Vitellus soil health gives a complete overview of the chemical status of a soil and allows us to identify differences between different production areas.

Soil health as it relates to yield is complicated. Underlying soil conditions; soil type, topsoil depth, compaction, pH, previous history and others all influence yield potential in a field. Satellite imagery is just a snapshot in time and often only gives a glimpse of crop potential. Weather through the remainder of the summer determines in part the eventual impact of various soil environments on crop yield.

Combining soil and topography maps, historical yield maps with imagery where possible allowed for better refinement of site selection and identification of poor and better yielding sites. Hand harvest samples ensured that yields came from exactly the area where the soil health sampled were taken. Given the degree of variability across fields this is important. There were a few pH measurements that were surprising in terms of lower pH on clay soils that had a history of higher pH. This may be due to the soil that was analyzed was from the root ball that was harvested.

Given that the paired samples were collected from the same field it is not surprising that many of the measured factors were very similar on a site basis. There is some year to year fluctuation among the indicators; Soil Organic Matter, General Fertility Index, Reactive Carbon and Wet Aggregate Stability tests appear the most consistent. Individual scores seem to tell more about what is going on in a soil and in future may be able to better inform management decisions as opposed to index or cumulative soil health scores.

Next Steps:

The final statistical analysis for the whole project will be completed shortly and the individual and final reports will be shared with cooperators at a wrap up meeting before April 2023.

Acknowledgements:

Thank you to the cooperators who provided the fields and management information for the sampling sites. Thank you to Chad Anderson for initiating the project. Thank you to Essex Region Conservation Authority, Lower Thames Region Conservation Authority and St Clair Region Conservation Authority for supporting a portion of the soil sampling. Thank you to Laura Van Eerd U of G, RC for the use of her lab and for her help in data analysis. Thank you to Inderjot Chahal for her work on the statistical analysis and Sean Vink for processing the hand harvest corn samples.

To OMAFRA summer students Cassandra Smids, Matt Vermey, Nicole Litwin and Ethan Brindley, thank you for help with sampling and signing the fields and running the aggregate stability samples. Thank you to Adam Hayes for his help with the first year and a half of the project, before retirement.

Thanks to Warriner Ag for donating their time to provide the field boundaries and for the collection and processing of the yield data in the first two years of the project. The NDVI imagery and additional help in 2020 especially by AGRIS Co-operative staff was greatly appreciated.

And finally, a huge thank you to Soledad Saldias and George Lazarovits at A and L Laboratories for their guidance on the project, analysis of the data and especially for the in-kind donation of the DNA analysis of the roots.

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Notes on the indicators:

General Fertility Index - is an index algorithm that is an overall calculation of field fertility based on the soil's nutrient composition. The soil nutrient optimum levels are based on soil type. The ranges of GFI Index are VL 0-35, L 35-55, M 55-65, G 65-80, H> 80

Solvita CO2-C (1 day burst) - This is the amount of CO2-C released in 24 hours from soil microbes after your soil has been dried and rewetted (as occurs naturally in the field). This is a measure of the microbial activity in the soil and is highly related to soil fertility. In most cases, the higher the number, the more fertile the soil.

Reactive Carbon – or active carbon is composed of all the dead and actively decomposing organic matter plus all the living soil microbial community that will

eventually die and begin decomposing. Reactive Carbon ranges based on the Cornell Assessment of Soil Health in ppm of Active Carbon for a medium Textured soil are Very Low 0-400, Low 400-500, Medium 500-600, High 600-700 and Very High >700.

Soil Health Index – an algorithm developed by A&L that considers the different chemical and physical parameters of the soil. This index ranges from 0 to 60 and highly correlates to yield and the presence of a combination of disease suppressive and bio-stimulating organisms in the plant microbiome (root zone).

% Microbial Active Carbon – %MAC – microbial active carbon is a measurement of how efficiently your soil microbes are using the carbon you are providing and can track the effects of changes in management and the impact of crop rotation and cover crops plus other soil amendments. %MAC = (Solvita 1 day burst CO2/Organic Carbon) x 100

NRCS Soil Health Calculation – uses Solvita CO2-C, C:N ratio and 2 other indicators

For further information on each year of the project see the appendices.

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2022 - Soil Health Analysis of Corn Fields- Final report

Client name	Date
St. Clair Region Soil and Crop Improvement Association 2018-2020 Tier 2 Project	Jan. 19, 2023

The **objective** of this work is to test how the A&L laboratories' VitTellus soil health analysis corelates with the yield and plant performance of corn in Ontario.

Methods

A&L received 80 corn roots with their respective root ball soil for analysis. These samples were collected by OMAFRA, Ridgetown office from eight corn fields in South-Western Ontario. Five plants were sample from each site based on NDVI maps identifying the locations as producing high yields or low producing areas for a total of 10 plants per field. The roots with their attached soil were code labelled, packaged individually, and sent to A&L for analysis (Table 1).

Table 1. List of samples received for analysis

Field	Samples	Samples
1	1A-1 to 5	1B-1 to 5
2	2A -1 to 5	2B-1 to 5
3	3A- 1 to 5	3B-1o 5
4	4A-1 to 5	4B-1 to 5
5	5A-1 to 5	5B-1 to 5
6	6A-1 to 5	6B-1 to 5
8	8A-1 to 5	8B-1 to 5
9	9A-1 to 5	9B-1 to 5

Upon receiving the samples, the soil was separated from the roots and sent for the VitTellus soil health analysis. A total of 80 soil samples were analysed. The roots from all 8 fields were washed with tap water, chopped into small pieces, and their DNA was extracted. The DNA was used to compare the root microbial communities (bacteria and fungi) of plants from the two areas within each field.

Soil Health Analysis: The VitTellus soil health uses the chemical parameters of the soil and some biological properties to calculate a relative Soil Health Index (SHI). This index ranges from 0 to 60, and the health of the soil is ranked as follow:

- SHI 0 – 20: very low soil health,
- SHI 20 – 30: low soil health,
- SHI 30 – 40: mediocre soil health,
- SHI 40 – 50: good soil health, and
- SHI 50 – 60: very good soil health

The VitTellus soil health test provides growers with an optimal range for crop productivity of chemical factors that our research has shown to be directly correlated with yield and those microbial activities favourable to plant health.

Analysis of the microbial communities: The root's microbial populations were analysed by Terminal Restriction Fragment Length Polymorphism (TRFLP). TRFLP is a fingerprinting technique for monitoring composition of microbial communities, and it can be used to track spatial and temporal shifts in microbial populations. Briefly, a conserved region of DNA extracted from roots (16S rRNA gene for bacteria and ITS gene for fungi) were amplified with fluorescently labeled primers. The fluorescent PCR products were then digested with a restriction enzyme. The size and quantity of the fragments were determined using capillary electrophoresis. The banding pattern obtained provides a fingerprint of the microbial community. The relationship of such fingerprints to one another was identified using a multivariate statistical technique called Principle Component Analysis (PCA). Principle Components (PC) are statistical values generated to best explain the variation in a set of samples. TRFLP data were transformed into binary data (is a specific peak present (1) or not (0)) before performing PCA. PCA analysis clustered the data based on similarity of peak presence; 95% confidence intervals were automatically drawn around each sample group. Groups that do not overlap are considered statistically different in their microbial community.

Yield: Yields were determined by OMAFRA, Ridgetown by hand harvesting the same areas from where the mid season samples were collected. Final yields were kindly provided to us by Anne Verhallen, Soil Management Specialist (Horticultural Crops), Ontario Ministry of Agriculture, Food and Rural Affairs, Ridgetown, Ontario.

Results

Field 1

Site B produced 11.1 more bu/ac than site A (site B: 285.3 bu/ac vs. site A 274.2 bu/ac).

A summary of the soil chemical analysis and yield of field 1 is presented in Table 2. The numbers represent the average per area (A or B). Full chemical analysis per sample can be found in the appendix. Occasionally we encountered results that exceeded typical values found within a replicate analysis of a specific group of samples. In such cases the outlier values were discarded. The averages of the results with the outliers, however, are presented in the appendix.

Both sites in this field had similar overall soil chemistry. Both sites had low organic matter (2.68% and 2.86%) and low K/Mg ratios (0.16 and 0.19). Our previous research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. In this field, both sites studied were below that ideal range. Both sites also had low pH values (site A = pH 5.42 and site B = pH 5.58).

Reactive Carbon is more complex than the Labile Carbon in that it is composed of all the dead and actively decomposing organic matter plus all the living soil microbial community that will eventually die and begin decomposing. Reactive carbon is linked to several soil processes, including microbial biomass growth and activity and nutrient cycling. Changes in the reactive carbon can happen very quickly and a significant decrease in reactive carbon may signal a decline in soil organic matter and indicates the deterioration of physical, chemical, and biological properties and processes related to soil organic matter. The adverse effects caused by the decline in reactive carbon include reduced aggregate stability, increased bulk density, and reduced water infiltration, water-holding capacity, microbial activity, and nutrient availability. Ranges in Reactive Carbon content as based on the Cornell Assessment of Soil Health in ppm of Active Carbon for a medium Textured soil are: Very Low 0-400, Low 400-500, Medium 500-600, High 600-700, and Very High >700. According to this scale Site A had medium levels of reactive carbon (565.8 ppm) while Site B had was at the bottom of the high level (608.2).

On average, site B had a 22% more water extractable organic carbon (217.7 ppm vs 178 ppm), higher GFI and SHI than site A (Site B GFI: 82.6, site A GFI: 70, site B SHI: 42.4, site A SHI: 36.4).

The slightly higher K/Mg ratio, pH, and reactive carbon of site B may have contributed to a yield benefit on this site.

Table 2. Soil Analysis of Field 1.

Parameters	1A	1B
Yield (bu/ac)	274.2	285.3
Organic Matter (OM, %)	2.68	2.86
Phopsphorus (Bicarb, ppm)	46	33
Phopsphorus (Bray, ppm)	122.6	78.8
Potassium (K, ppm)	78.2	85.8
Magnesium (Mg, ppm)	147.8	137.4
Calcium (Ca, ppm)	1148	1084
Sodium (Na, ppm)	16.6	13.4
Sulfur (S, ppm)	16.8	14.2
Zinc (Zn, ppm)	8.58	6.3
Manganese (Mn, ppm)	12	9
Iron (Fe, ppm)	96.8	92
Copper (Cu, ppm)	2.4	2.46
Boron (B, ppm)	0.58	0.54
Aluminum (Al, ppm)	855.4	853
CEC (meq/ 100g)	9.14	9.22
K/Mg Ratio	0.16	0.19
General Fertility Index (GFI)	70	82.6
Percent Base Saturation %K	2.22	2.4
%Mg	13.78	12.5
%Ca	64.1	59.06
%H	19.08	25.38
%Na	0.82	0.64
pH	5.42	5.58
Buffer pH	6.84	6.8
EC (ms/cm)	0.218	0.196
Saturation %P	18.4	11.8
Saturation %Al	2.12	1.7
Nitrate-N (ppm)	3.6	2.8
Chloride (ppm)	22.8	13.8
Potential Mineralizable Nitrogen (PMN, ppm)	76.4	78
Water Extracted Organic C (ppm)	178	217.7
Water Extracted Inorganic N (ppm)	6.47	5.818
Water Extracted Organic N (ppm)	25.53	27.142
Solvita CO2-C (ppm)	67	69
Reactive C (ppm)	565.8	608.2
Soil Health Index	36.4	42.4
%Microbial Active Carbon (MAC)	40.82	31.84
Organic C:N ratio	7.04	8.28
NRCS Soil Health Calculations	10.56	11.8
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	38.8	32.642
Water extracted total N	32	33
Water extracted Soil Nitrate	3.8	3.4
Water extracted Soil Ammonium	2.6	2.2

NRCS soil health calculations based on the Haney test results

Microbial communities

The composition of the bacterial and fungal communities of roots from sites A and B were analysed using TRFLP. We compared the microbial communities from both sites and summarized the results in two different ways: **(A) As vectors:** Figures 1A and 2A show each TRFLP result as a vector (bacterial and fungal, respectively). Each vector represents the community of one plant (named 1- 5). The closer the vectors are to each other, the more similar are the populations they represent. **(B) As single data point:** To visualize if there were any statistically significant differences between the communities from site A and B, we summarized our results as single data points and plotted them two dimensionally (Figures 1B and 2B). The degree of separation between dots indicates the extent of similarities or differences. The further the dots are separated, the greater the difference. The closer they are, the more similar the population. Confidence circles (95%) that do not overlap are considered significantly different.

As shown on Figure 1A, four out of the five replicates from site A grouped in a different quadrant than the vectors from site B, suggesting that the microbial composition from both sites were different. The differences were not significant however, due to one replication from site A grouping together with the samples from site B (Figure 1B). We cannot discard the possibility that a mistake was made during the processing of that replicate. Differences between the soil bacterial communities of site A and B could not be confirmed.

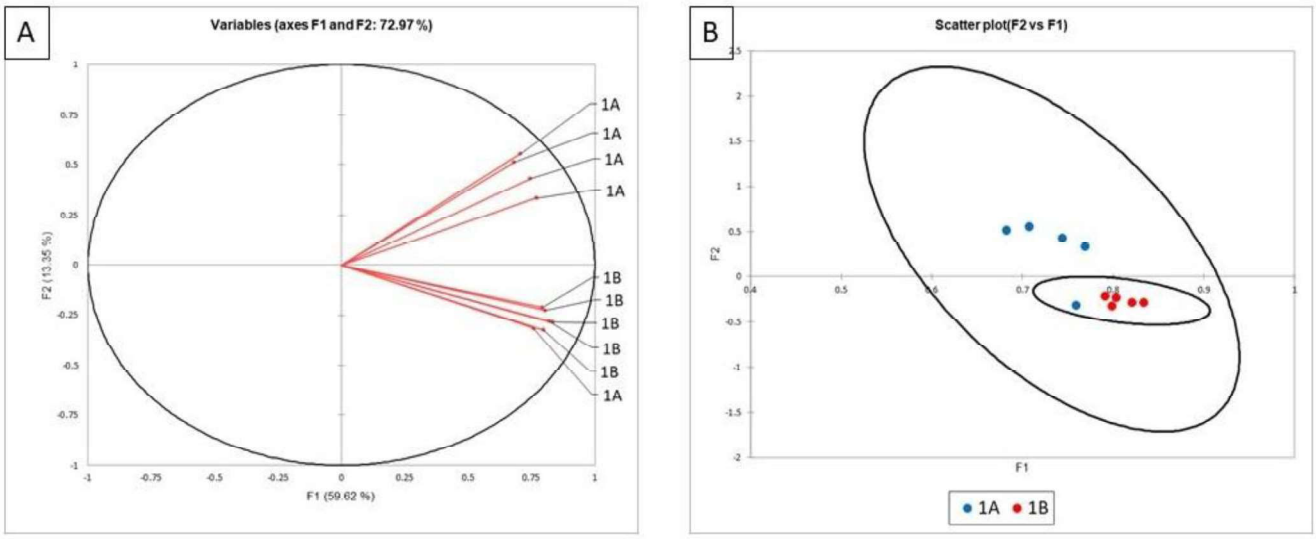

Figure 1. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 1. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

No differences in the fungal communities of roots from site A and B were found (Figure 2A and B). All samples clustered together indicating that their fungal communities were similar.

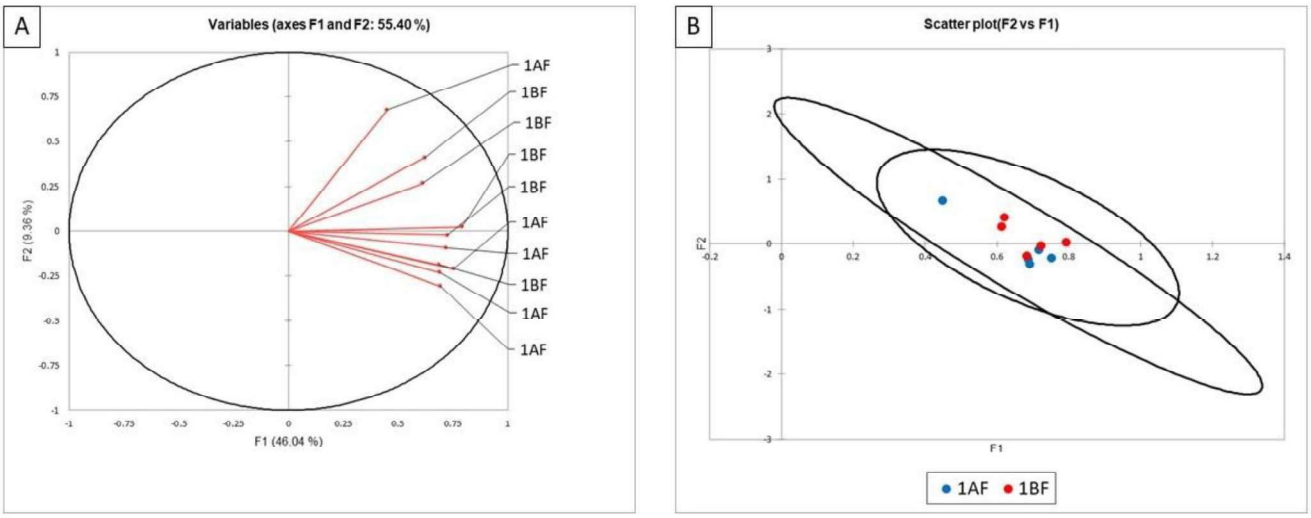

Figure 2. Statistical analysis of TRFLP of the fungal communities in corn roots of field 1. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 2

Site A produced 60.8 bu/ac more than site B (site A: 196.7 bu/ac vs. site B 135.9 bu/ac). A summary of the soil chemical analysis and yield of field 2 is presented in Table 3.

In this field, both sites had similar soil chemistry values across many of the key parameters. Both sites had moderate to low GFI values (63.2 site A vs 66 site B), moderate SHI values (33.8 site A vs 34.8 site B), low K/Mg ratios (0.116 site A vs. 0.174 site B) and high reactive carbon values (628.4 site A vs. 646.4 site B).

The 2 parameters that did show large differences between site A and B were pH and % microbial active carbon (MAC). Site A had a good pH (6.06) while site B had a low pH (4.82). Site A had a higher percent microbial active carbon than site B (31.16 site A vs. 21.6 site B). Difference in pH likely had an impact on the microbial communities as well.

Table 3. Soil Analysis of Field 2.

Parameters	2A	2B
Yield (bu/ac)	196.7	135.9
Organic Matter (OM, %)	2.7	3.14
Phopsphorus (Bicarb, ppm)	21.8	36.6
Phopsphorus (Bray, ppm)	37.2	70.6
Potassium (K, ppm)	92.4	102.6
Magnesium (Mg, ppm)	252.4	181.8
Calcium (Ca, ppm)	1416	1166
Sodium (Na, ppm)	16.8	22.8
Sulfur (S, ppm)	8	11
Zinc (Zn, ppm)	3.94	4.08
Manganese (Mn, ppm)	21.8	13.6
Iron (Fe, ppm)	76.2	105.4
Copper (Cu, ppm)	1.6	1.4
Boron (B, ppm)	0.64	0.5
Aluminum (Al, ppm)	633.4	842.8
CEC (meq/ 100g)	10.88	15.84
K/Mg Ratio	0.116	0.174
General Fertility Index (GFI)	63.2	66
Percent Base Saturation %K	2.18	1.68
%Mg	19.28	9.72
%Ca	64.84	37.44
%H	13.06	50.52
%Na	0.68	0.64
pH	6.06	4.82
Buffer pH	6.88	6.32
EC (ms/cm)	0.172	0.178
Saturation %P	7.4	10.8
Saturation %Al	0.52	3.04
Nitrate-N (ppm)	2.6	1.8
Chloride (ppm)	19	19.8
Potential Mineralizable Nitrogen (PMN, ppm)	82.8	80
Water Extracted Organic C (ppm)	246.62	335.76
Water Extracted Inorganic N (ppm)	7.556	8.66
Water Extracted Organic N (ppm)	27.444	33.88
Solvita CO2-C (ppm)	76.6	72.4
Reactive C (ppm)	628.4	646.4
Soil Health Index	33.8	34.8
%Microbial Active Carbon (MAC)	31.16	21.6
Organic C:N ratio	9.12	10.3
NRCS Soil Health Calculations	12.86	14
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	39	43.4
Water extracted total N	35.4	42.4
Water extracted Soil Nitrate	4.4	4
Water extracted Soil Ammonium	3.4	4.8

NRCS soil health calculations based on the Haney test results.

Microbial communities

As shown in Figures 3 (A and B), the bacterial communities of the roots from site A grouped tightly together and site B grouped close by but not as tight. This indicates that the bacterial communities from site A and B were different, but the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 3B). Similar results were observed for the fungal communities of site A and B (Figure 4). The TRFLP results for field 2 indicated that there are clear differences in the both the bacterial and fungal communities between the 2 sites sampled within the field. This is likely impacted by the differences in pH at the two sites (A = 6.06 and B = 4.82). More alkaline soils are bacterial dominant whereas acidic soils are fungal dominant.

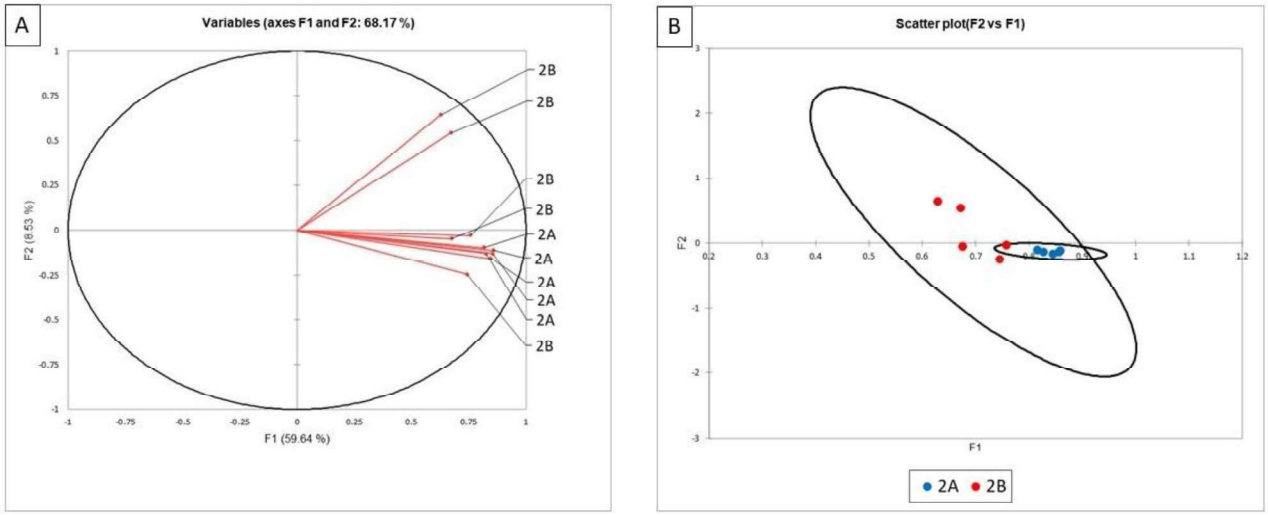

Figure 3. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 2. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

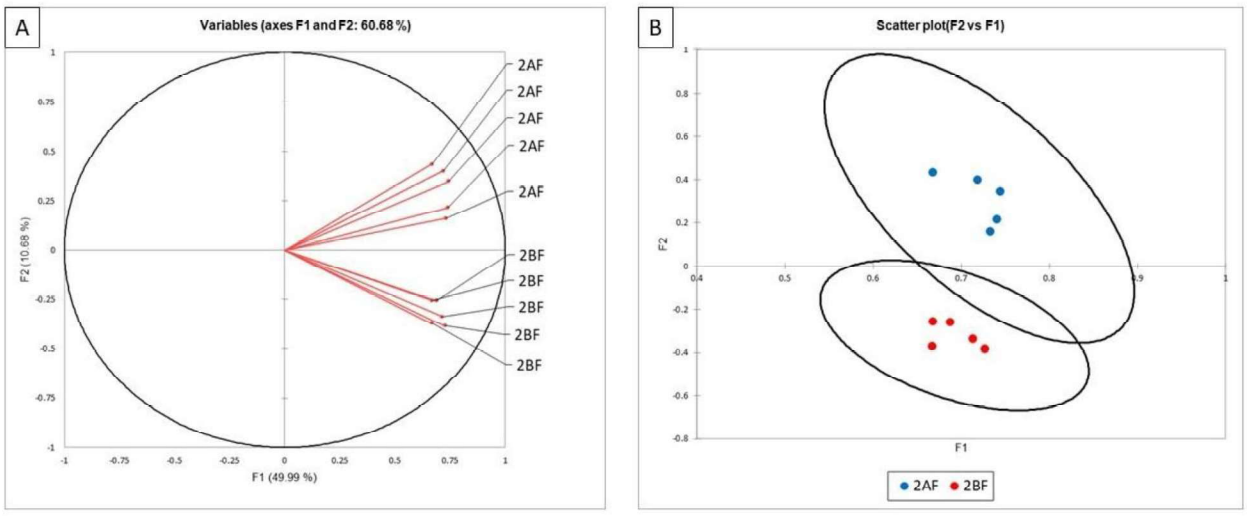

Figure 4. Statistical analysis of TRFLP of the fungal communities in corn roots of field 2. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 3

Site A produced 12.7 bu/ac more than site B (site A: 165.4 bu/ac vs. site B 152.7 bu/ac). Both sites produced lower than average yields. A summary of the soil chemical analysis and yield of field 3 is presented in Table 4.

In this field both sites had high levels of organic matter (4.62% site A and 5.2% site B) and very high levels of reactive carbon (825.2 site A and 802.8 site B). Both sites had moderate GFI values (57.8 site A and 56.4 site B) and moderate SHI values (31.6 site A and 30.4 site B).

Both sites had very low K/Mg ratios (0.066 site A and 0.088 site B) which could account for the lower yields. Our previous research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. Potash application should benefit the productivity at both sites. Site A had a higher pH (6.76 vs 5.6), higher CO2-C (84.6 ppm vs70.4 ppm) and percent microbial activity (32.64 vs. 23.36) than site B. Solvita CO_2-C measures the microbial activity in the soil and highly related to soil fertility. The differences in these parameters may have provided a yield benefit to this site.

Table 4. Soil Analysis of Field 3.

Parameters	3A	3B
Yield (bu/ac)	165.4	152.7
Organic Matter (OM, %)	4.62	5.2
Phopsphorus (Bicarb, ppm)	39.8	27.6
Phopsphorus (Bray, ppm)	67.8	48.4
Potassium (K, ppm)	136.2	146.8
Magnesium (Mg, ppm)	651.4	530
Calcium (Ca, ppm)	2444	2414
Sodium (Na, ppm)	21.8	21.4
Sulfur (S, ppm)	10.8	10.6
Zinc (Zn, ppm)	6	4.08
Manganese (Mn, ppm)	12.4	4.2
Iron (Fe, ppm)	95.6	126
Copper (Cu, ppm)	2.18	2.68
Boron (B, ppm)	0.5	0.5
Aluminum (Al, ppm)	846.4	970.6
CEC (meq/ 100g)	19.2	26.02
K/Mg Ratio	0.066	0.088
General Fertility Index (GFI)	57.8	56.4
Percent Base Saturation %K	1.84	1.48
%Mg	28.2	17.02
%Ca	63.58	46.54
%H	5.92	34.64
%Na	0.5	0.36
pH	6.76	5.6
Buffer pH	6.9	6.24
EC (ms/cm)	0.248	0.242
Saturation %P	10	6.6
Saturation %Al	0.12	0.62
Nitrate-N (ppm)	5.8	5.4
Chloride (ppm)	8.8	7
Potential Mineralizable Nitrogen (PMN, ppm)	43.4	39.6
Water Extracted Organic C (ppm)	259.72	304.5
Water Extracted Inorganic N (ppm)	12.0186	13.848
Water Extracted Organic N (ppm)	33.1414	25.392
Solvita CO2-C (ppm)	84.6	70.4
Reactive C (ppm)	825.2	802.8
Soil Health Index	31.6	30.4
%Microbial Active Carbon (MAC)	32.64	23.26
Organic C:N ratio	8.5	11.94
NRCS Soil Health Calculations	20.36	12.66
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	58.8	65
Water extracted total N	45.2	39.6
Water extracted Soil Nitrate	9.6	10.8
Water extracted Soil Ammonium	2.6	3

NRCS soil health calculations based on the Haney test results.

Microbial communities

As shown in Figures 5 (A and B), the bacterial communities of the roots from site A grouped tightly together and site B grouped close by but not as tight. This indicates that the bacterial communities from site A and B were different, but the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 5B). Similar results were observed for the fungal communities of site A and B (Figure 6). The TRFLP results for field 3 indicated that there are clear differences in the both the bacterial and fungal communities between the 2 sites sampled within the field. This is likely impacted by the differences in pH at the two sites (A = 6.76 and B = 5.6). More alkaline soils are bacterial dominant whereas acidic soils are fungal dominant.

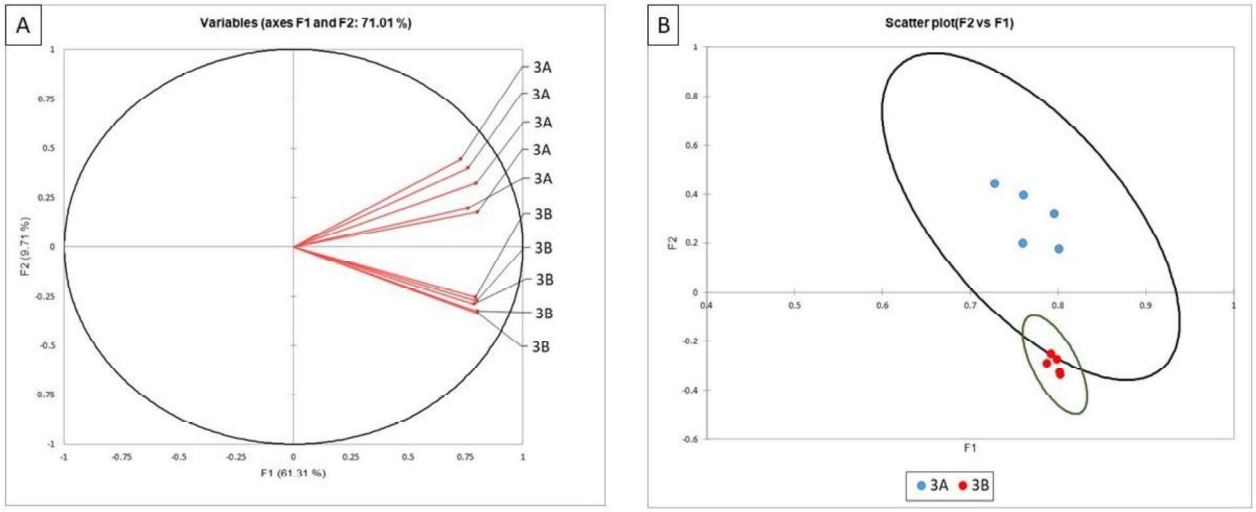

Figure 5. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 3. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

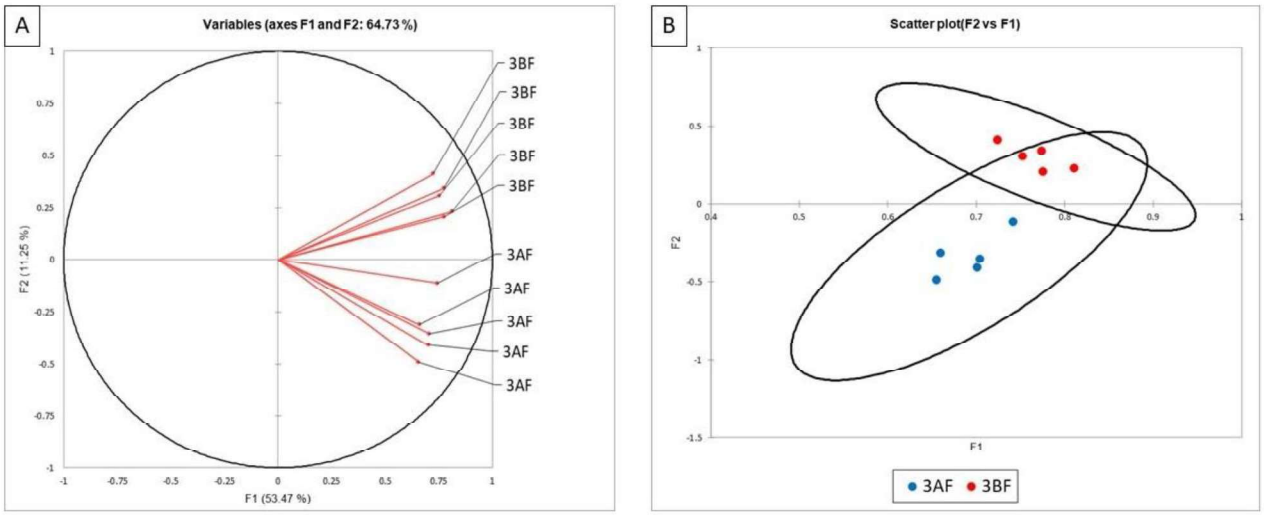

Figure 6. Statistical analysis of TRFLP of the fungal communities in corn roots of field 3. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 4

Site A produced 42.8 bu/ac more than site B (site A: 136.3 bu/ac vs. site B 93.3 bu/ac). Both sites produced lower than average yields. A summary of the soil chemical analysis and yield of field 4 is presented in Table 5.

Site A had higher % saturation of phosphorus (12.2 vs 6.8) and higher levels of nitrate (30.4 pp vs 12 ppm) than site B. Both sites had good organic matter levels (3.44% site A and 3.9% site B), good pH values (6.9 site A and 7.26 site B), good GFI values (72.6 site A and 67.6 site B), and moderate SHI values (39.2 site A and 37.4 site B).

Site A had a higher percent microbial activity than site B (62.54 site A and 49.7 site B). Site B had higher reactive carbon than site A (764.8 site B and 540.8 site A). The reactive carbon for site B was considered very high and the reactive carbon for site A was considered moderate.

Table 5. Soil Analysis of Field 4.

Parameters	4A	4B
Yield (bu/ac)	136.3	93.3
Organic Matter (OM, %)	3.44	3.9
Phopsphorus (Bicarb, ppm)	38	45.8
Phopsphorus (Bray, ppm)	80.6	89
Potassium (K, ppm)	103.4	130.4
Magnesium (Mg, ppm)	198.8	258.8
Calcium (Ca, ppm)	2614	3468
Sodium (Na, ppm)	24	27.8
Sulfur (S, ppm)	9.4	10.6
Zinc (Zn, ppm)	19.78	14.7
Manganese (Mn, ppm)	203.2	92.4
Iron (Fe, ppm)	64.6	66
Copper (Cu, ppm)	7.08	5.6
Boron (B, ppm)	0.74	0.88
Aluminum (Al, ppm)	592.8	589
CEC (meq/ 100g)	16.9	20.68
K/Mg Ratio	0.16	0.156
General Fertility Index (GFI)	72.6	67.6
Percent Base Saturation %K	1.58	1.6
%Mg	9.9	10.42
%Ca	77.34	83.84
%H	10.58	3.6
%Na	0.62	0.58
pH	6.9	7.26
Buffer pH	6.96	7
EC (ms/cm)	0.43	0.33
Saturation %P	12.2	6.8
Saturation %Al	0.1	0
Nitrate-N (ppm)	30.4	12
Chloride (ppm)	11.8	11.4
Potential Mineralizable Nitrogen (PMN, ppm)	46	47.4
Water Extracted Organic C (ppm)	153.84	209.92
Water Extracted Inorganic N (ppm)	35.424	18.15
Water Extracted Organic N (ppm)	26.038	30.35
Solvita CO2-C (ppm)	95.6	104.8
Reactive C (ppm)	540.8	764.8
Soil Health Index	39.2	37.4
%Microbial Active Carbon (MAC)	62.54	49.7
Organic C:N ratio	6.14	7.2
NRCS Soil Health Calculations	13.04	15.58
Biological Soil Quality	4.2	4.2
Estimated Nitrogen Release (ENR, lb/ac/year)	46.4	51
Water extracted total N	61.4	48.6
Water extracted Soil Nitrate	33.2	17.2
Water extracted Soil Ammonium	2.4	1

NRCS soil health calculations based on the Haney test results.

Microbial communities

As shown in Figures 7 (A and B), the bacterial communities of the roots from site A grouped tightly together and site B grouped close by but not as tight. This indicates that the bacterial communities from site A and B were different, but the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 7B). Similar results were observed for the fungal communities of site A and B (Figure 8). The TRFLP results for field 4 indicated that there are clear differences in the both the bacterial and fungal communities between the 2 sites sampled within the field.

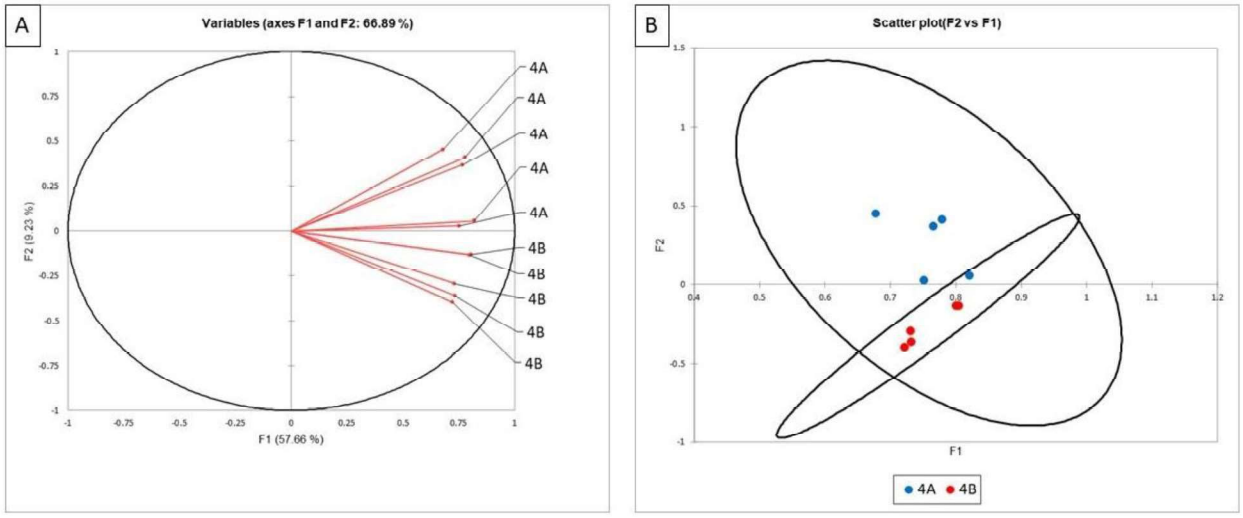

Figure 7. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 4. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

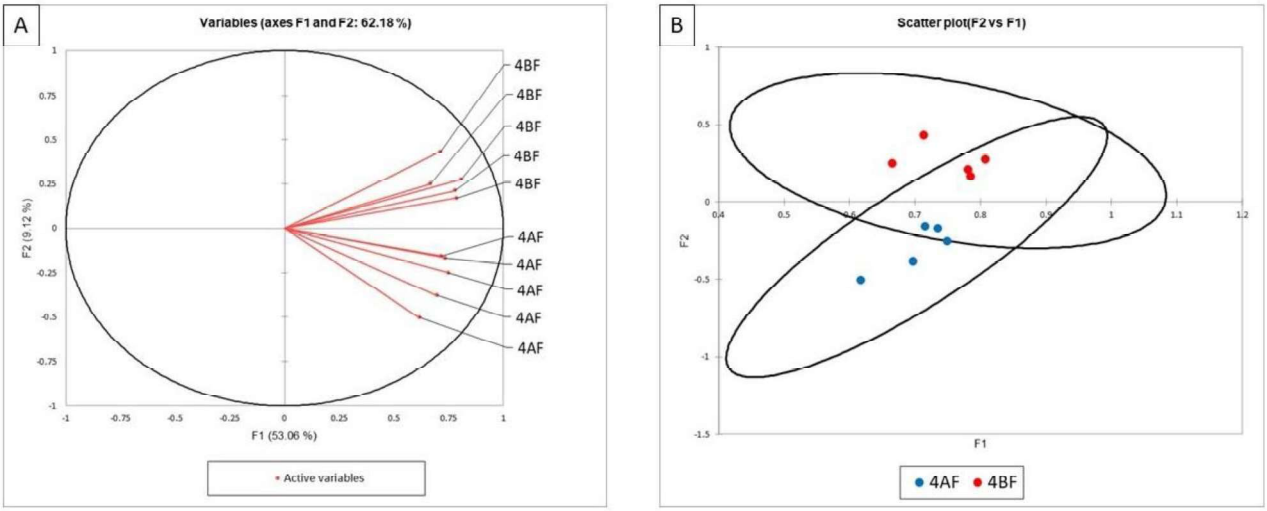

Figure 8. Statistical analysis of TRFLP of the fungal communities in corn roots of field 4. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 5

A summary of the soil chemical analysis and yield of field 4 is presented in Table 5. No yield data was provided for field 5.

Both sites had high organic matter (5.26% site A and 5.54% site B), good GFI values (67.4 site A and 64 site B), moderate SHI values (37.2 site A and 35.6 site B) and good pH (6.92 site A and 7.14 site B).

Site B had higher levels than site A in multiple parameters including Phosphorus bicarb (84.2ppm vs. 32.4ppm), Phosphorus bray (212 ppm vs. 59.4 ppm), % saturation of phosphorus (41.4 vs 10.4), Potassium (509 ppm vs. 200.8 ppm) and % saturation of potassium (6.5 vs 2.4), Sodium (34.2 ppm vs. 16.4 ppm), Sulfur (23.2 ppm vs. 7.6 ppm), Zinc (72.28 ppm vs. 8.38 ppm), and % saturation of Mg (24.1 vs 20.4).

Site B also had a K/Mg ratio of 0.27 which falls within the ideal range for that parameter and site A had a K/Mg ratio of 0.118 which is below the ideal range.

Table 6. Soil Analysis of Field 5.

Parameters	5A	5B
Yield (bu/ac)	N/A	N/A
Organic Matter (OM, %)	5.26	5.54
Phopsphorus (Bicarb, ppm)	32.4	84.2
Phopsphorus (Bray, ppm)	59.4	212
Potassium (K, ppm)	200.8	509
Magnesium (Mg, ppm)	519.2	582
Calcium (Ca, ppm)	3004	2484
Sodium (Na, ppm)	16.4	34.2
Sulfur (S, ppm)	7.6	23.2
Zinc (Zn, ppm)	8.38	72.28
Manganese (Mn, ppm)	87	21.8
Iron (Fe, ppm)	91.6	127.2
Copper (Cu, ppm)	2.54	2.48
Boron (B, ppm)	0.84	1.04
Aluminum (Al, ppm)	720.6	656.8
CEC (meq/ 100g)	21.2	20.18
K/Mg Ratio	0.118	0.27
General Fertility Index (GFI)	67.4	64
Percent Base Saturation %K	2.4	6.5
%Mg	20.4	24.1
%Ca	70.78	61.86
%H	6.06	6.84
%Na	0.32	0.74
pH	6.92	7.14
Buffer pH	6.92	7
EC (ms/cm)	0.224	0.288
Saturation %P	10.4	41.4
Saturation %Al	0.1	0.06
Nitrate-N (ppm)	3.4	3.2
Chloride (ppm)	7.6	44.6
Potential Mineralizable Nitrogen (PMN, ppm)	46.6	42.4
Water Extracted Organic C (ppm)	227.34	298.58
Water Extracted Inorganic N (ppm)	6.682	5.064
Water Extracted Organic N (ppm)	21.098	27.276
Solvita CO2-C (ppm)	97.4	82
Reactive C (ppm)	770.4	1078.4
Soil Health Index	37.2	35.6
%Microbial Active Carbon (MAC)	42.92	27.72
Organic C:N ratio	10.92	10.98
NRCS Soil Health Calculations	14.12	13.98
Biological Soil Quality	4.4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	65.6	68.4
Water extracted total N	27.2	32.2
Water extracted Soil Nitrate	5.2	3
Water extracted Soil Ammonium	0.8	1.8

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities of roots from sites A and B in this field (Figures 9A and B).

As shown in Figures 10 (A and B), the fungal communities of the roots from site A grouped together and the fungal communities from site B also grouped together. This indicates that the fungal communities from site A and B were different, but the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 10B).

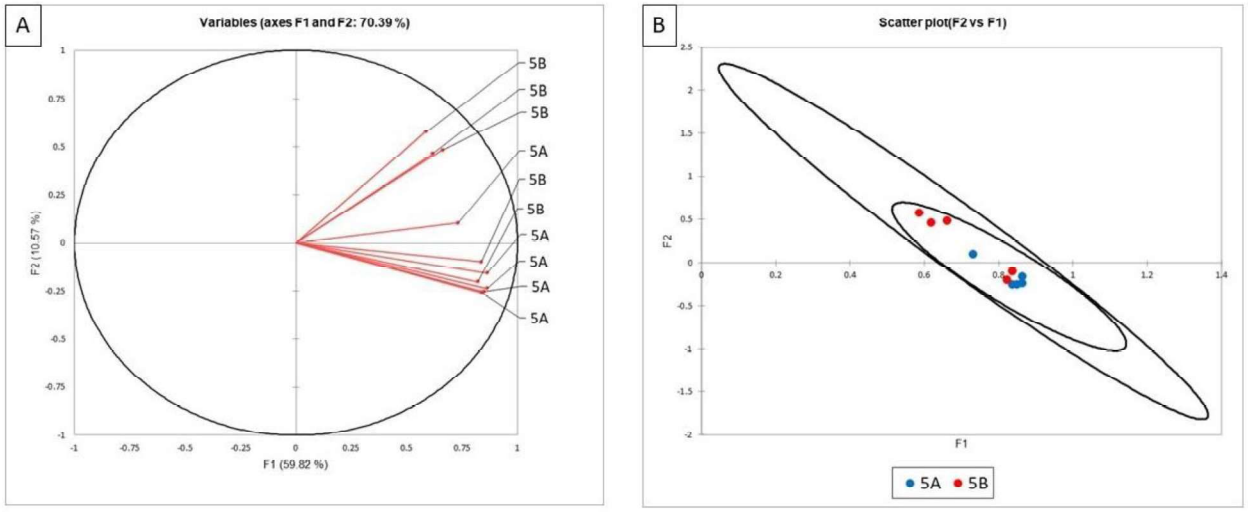

Figure 9. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 5. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

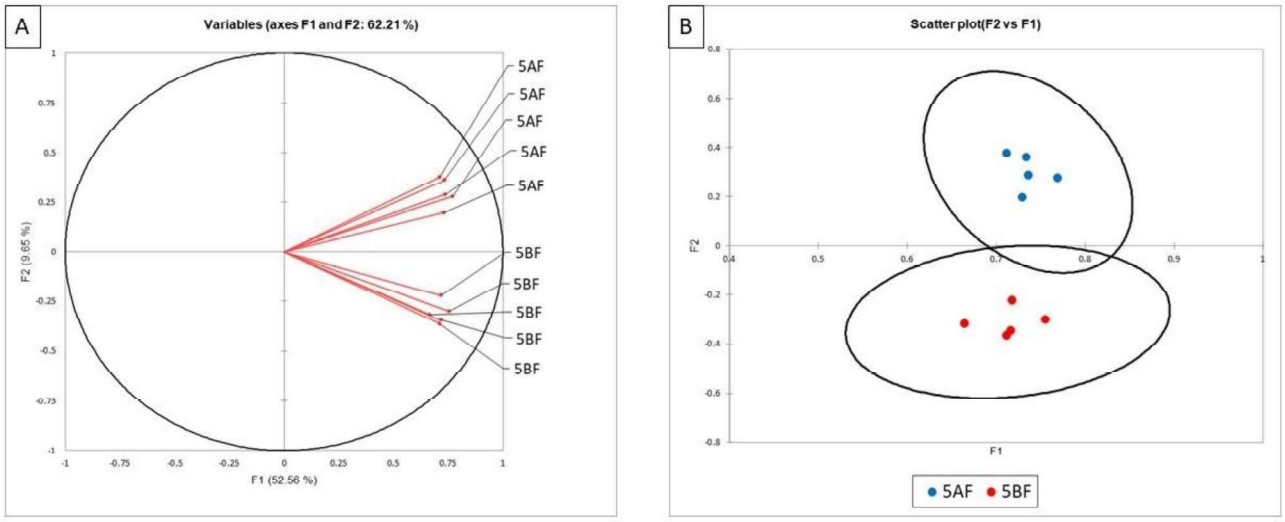

Figure 10. Statistical analysis of TRFLP of the fungal communities in corn roots of field 5. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 6

Site A produced 22.2 bu/ac more than site B (site A: 205.8 bu/ac vs. site B 183.6 bu/ac). A summary of the soil chemical analysis and yield of field 4 is presented in Table 5.

Site A had a higher GFI and SHI than site B (76 vs 61.4 and 40.6 vs. 32.2). The GFI and SHI for site A were both considered good and the GFI and SHI for site B were considered moderate. Site A also had higher microbial respiration rates (81 vs 50.2), reactive carbon (732.2 vs. 545.4) and percent microbial active carbon (65.88 vs. 49.8) than site B.

Site A had higher Potassium (144.2ppm vs. 118.8ppm) and % saturation of potassium (3.86 vs 1.62), Magnesium (212.2ppm vs. 146.8ppm) an % saturation of magnesium (18.42 vs 6.6), % saturation of phosphorus (11.6 vs 8), and Aluminum (649.4ppm vs. 292.6ppm) than site B.

The yield results support differences observed in the soil chemistry and microbial communities. present in each site.

Table 7. Soil Analysis of Field 6.

Parameters	6A	6B
Yield (bu/ac)	205.8	183.6
Organic Matter (OM, %)	2.8	2.26
Phopsphorus (Bicarb, ppm)	27.6	53.4
Phopsphorus (Bray, ppm)	60.2	112.6
Potassium (K, ppm)	144.2	118.8
Magnesium (Mg, ppm)	212.2	146.8
Calcium (Ca, ppm)	1246	3394
Sodium (Na, ppm)	10.6	14.4
Sulfur (S, ppm)	10.8	15.8
Zinc (Zn, ppm)	5.5	8.86
Manganese (Mn, ppm)	46	90.6
Iron (Fe, ppm)	64.4	48.8
Copper (Cu, ppm)	3.34	3.38
Boron (B, ppm)	0.72	0.98
Aluminum (Al, ppm)	649.4	292.6
CEC (meq/ 100g)	9.6	18.54
K/Mg Ratio	0.208	0.246
General Fertility Index (GFI)	76	61.4
Percent Base Saturation %K	3.86	1.62
%Mg	18.42	6.6
%Ca	64.92	91.54
%H	12.26	0
%Na	0.48	0.32
pH	6.4	7.76
Buffer pH	6.9	7
EC (ms/cm)	0.188	0.274
Saturation %P	11.6	8
Saturation %Al	0.36	0
Nitrate-N (ppm)	3.6	2.2
Chloride (ppm)	24.2	15.6
Potential Mineralizable Nitrogen (PMN, ppm)	41.8	32.6
Water Extracted Organic C (ppm)	120.98	100.836
Water Extracted Inorganic N (ppm)	5.74	4.236
Water Extracted Organic N (ppm)	12.766	10.636
Solvita CO2-C (ppm)	81	50.2
Reactive C (ppm)	732.2	545.4
Soil Health Index	40.6	32.2
%Microbial Active Carbon (MAC)	65.88	49.8
Organic C:N ratio	9.52	9.56
NRCS Soil Health Calculations	10.54	7.1
Biological Soil Quality	4.2	4
Estimated Nitrogen Release (ENR, lb/ac/year)	40	34.6
Water extracted total N	18.2	14.6
Water extracted Soil Nitrate	5.2	3.4
Water extracted Soil Ammonium	1	1.2

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site B clustered together, as evident from the clustering of the samples on the bottom right quadrant of the graph (Figure 11A). The root's bacterial populations from site A were also clustered together, as indicated by the clustering of the samples on the top right quadrant of the graph (Figure 11A). The differences in the bacterial communities of the roots were statistically significant as indicated by the clear separation of the ellipses (Figure 11B).

The fungal communities of roots from site A and site B are clearly different and cluster together (Figure 12). However, the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 12B).

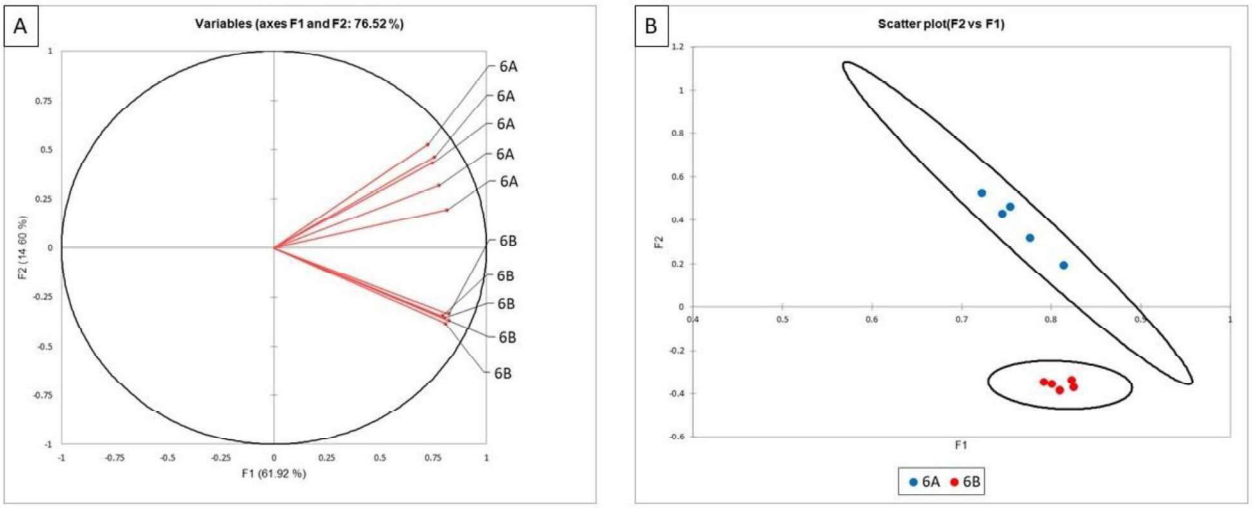

Figure 11. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 6. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

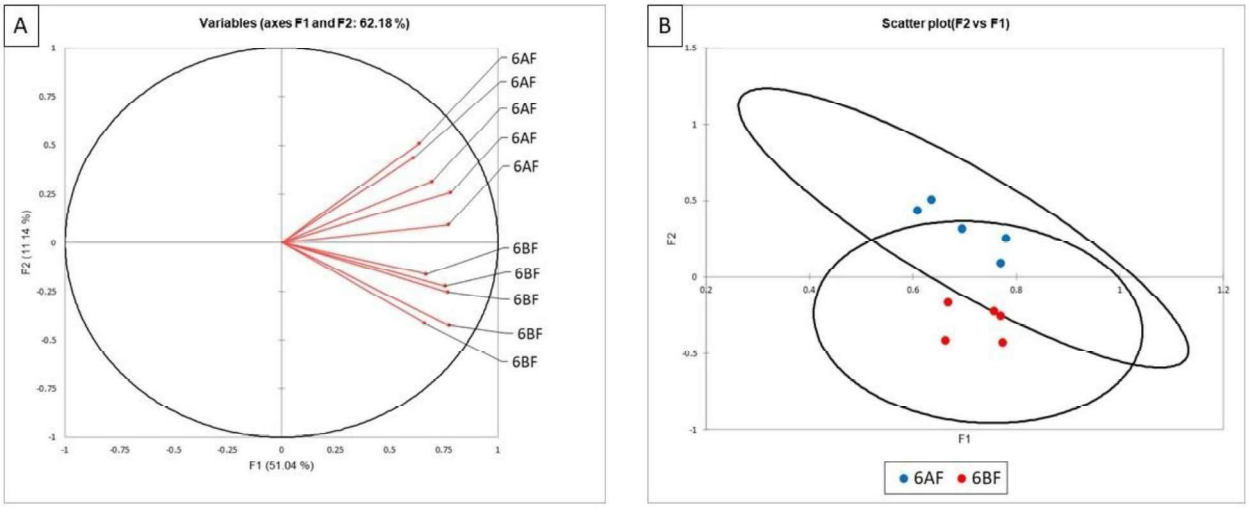

Figure 12. Statistical analysis of TRFLP of the fungal communities in corn roots of field 6. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 8

Site B produced 52.7 bu/ac more than site B (site A: 87.8 bu/ac vs. site B 140.5 bu/ac). Both sites produced lower than average yields. A summary of the soil chemical analysis and yield of field 4 is presented in Table 5.

Site B had higher Phosphorus bicarb (13ppm vs. 6.2ppm), Phosphorus bray (21ppm vs. 9.2ppm) and % saturation of phosphorus (3.6 vs 1.4), microbial respiration (78.4ppm vs. 61ppm), reactive carbon (558 ppm vs. 474.2 ppm) and percent microbial activity (41.62 vs. 35.32) than site A.

The GFI (55.4 site A and 58.2 site B) and SHI (29.4 site A and 31.8 site B) were slightly higher in Site B. The GFI for both sites were considered low. The SHI for site A was considered low and moderate for site B.

The soil chemistry for both sites in this field were very similar and the results are mirrored in the TRFLP data presented below. Both the bacterial and fungal communities on the roots are very similar between the 2 sites.

The differences in the Phosphorus, microbial respiration, reactive carbon, and percent microbial activity could be contributing to the yield increase observed in site B.

Table 8. Soil Analysis of Field 8.

Parameters	8A	8B
Yield (bu/ac)	87.8	140.5
Organic Matter (OM, %)	3.22	3.12
Phopsphorus (Bicarb, ppm)	6.2	13
Phopsphorus (Bray, ppm)	9.2	21
Potassium (K, ppm)	110.8	115
Magnesium (Mg, ppm)	257.6	272.4
Calcium (Ca, ppm)	2144	1844
Sodium (Na, ppm)	13.6	15
Sulfur (S, ppm)	7.8	9.2
Zinc (Zn, ppm)	1.72	3.48
Manganese (Mn, ppm)	4.4	3.4
Iron (Fe, ppm)	77.6	82.6
Copper (Cu, ppm)	2.04	1.68
Boron (B, ppm)	0.92	0.98
Aluminum (Al, ppm)	782.6	719.2
CEC (meq/ 100g)	14.38	13.04
K/Mg Ratio	0.132	0.13
General Fertility Index (GFI)	55.4	58.2
Percent Base Saturation %K	2	2.24
%Mg	14.94	17.42
%Ca	74.52	70.8
%H	8.14	9
%Na	0.4	0.52
pH	6.48	6.14
Buffer pH	6.9	6.9
EC (ms/cm)	0.182	0.186
Saturation %P	1.4	3.6
Saturation %Al	0.24	0.44
Nitrate-N (ppm)	1.4	1.8
Chloride (ppm)	13.6	17
Potential Mineralizable Nitrogen (PMN, ppm)	97.4	41.8
Water Extracted Organic C (ppm)	176.64	190.04
Water Extracted Inorganic N (ppm)	4.32	5.53
Water Extracted Organic N (ppm)	14.85	17.28
Solvita CO2-C (ppm)	61	78.4
Reactive C (ppm)	558	474.2
Soil Health Index	29.4	31.8
%Microbial Active Carbon (MAC)	35.32	41.62
Organic C:N ratio	11.92	11.04
NRCS Soil Health Calculations	9.32	11.5
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	44.2	43.2
Water extracted total N	19	22.8
Water extracted Soil Nitrate	3.2	3.6
Water extracted Soil Ammonium	1	1.4

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities of roots from sites A and B in this field (Figures 13A and B). Similarly, no differences were found in the fungal communities of roots in the field (Figures 14A and B).

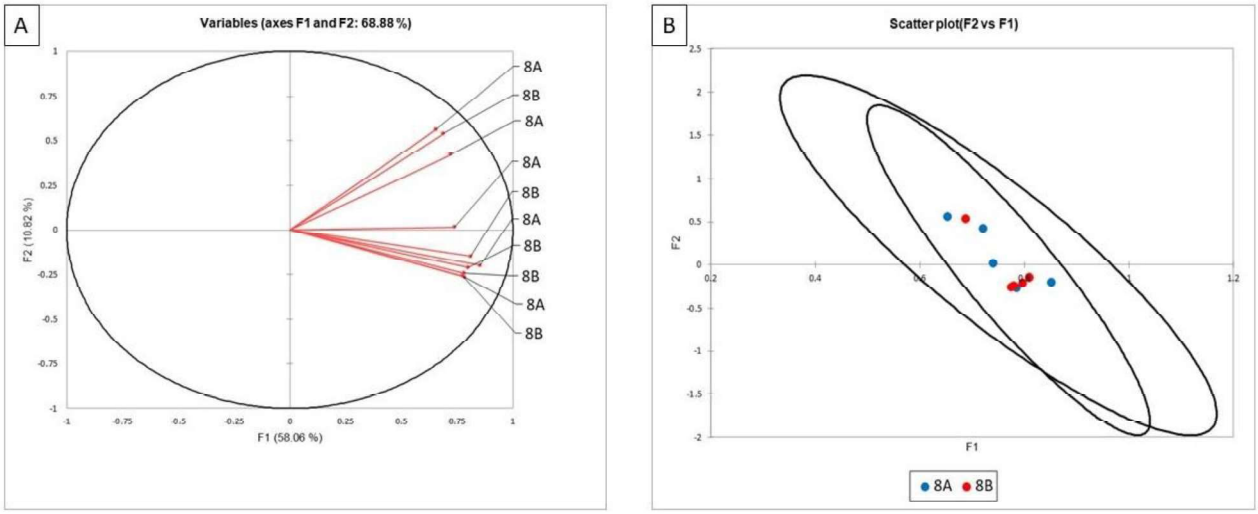

Figure 13. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 8. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

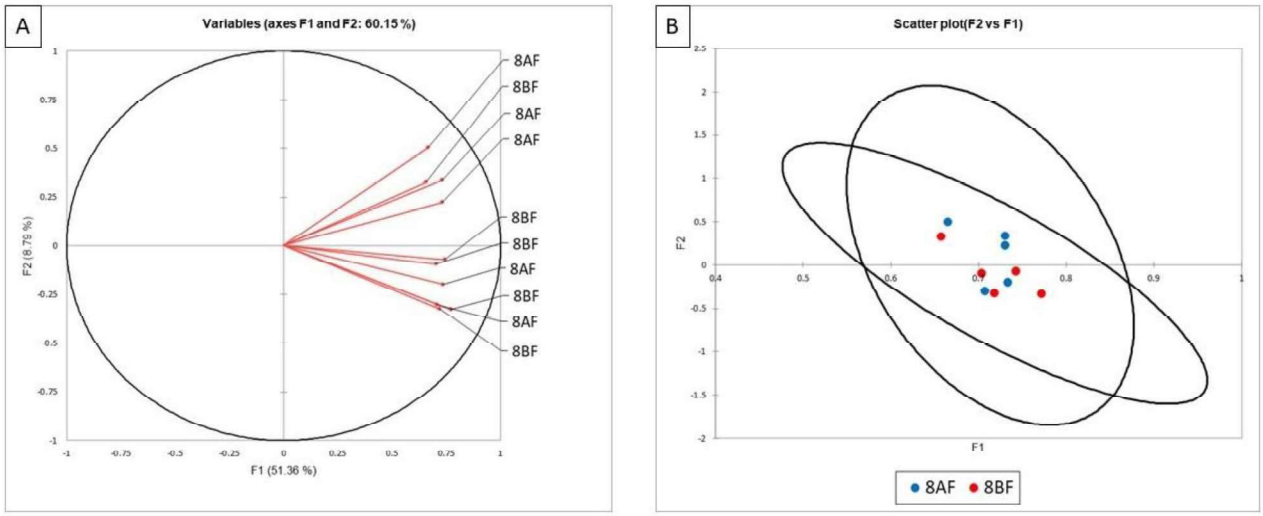

Figure 14. Statistical analysis of TRFLP of the fungal communities in corn roots of field 8. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 9

Site B produced 6.1 bu/ac more than site A (site A: 187.7 bu/ac vs. site B 193.8 bu/ac). A summary of the soil chemical analysis and yield of field 4 is presented in Table 9.

Both sites in this field had good K/Mg ratios (0.224 site A and 0.226 site B), good GFI (71.4 site A and 79.6 site B) and moderate SHI (36.4 site A and 40.8 site B).

The soil chemistry for the 2 sites was very similar and is reflected in the small difference in yield for each site.

Some clear difference in the bacterial and fungal communities in the roots from both sites were observed (data presented below) and could be explained by the difference in pH between the 2 sites (7.24 site A and 5.9 site B).

Table 9. Soil Analysis of Field 9.

Parameters	9A	9B
Yield (bu/ac)	187.7	193.8
Organic Matter (OM, %)	2	2.64
Phopsphorus (Bicarb, ppm)	56.2	59.8
Phopsphorus (Bray, ppm)	139.6	161.8
Potassium (K, ppm)	124	165.2
Magnesium (Mg, ppm)	169	224
Calcium (Ca, ppm)	1900	1298
Sodium (Na, ppm)	13.4	12.8
Sulfur (S, ppm)	15.8	19
Zinc (Zn, ppm)	11.26	12.98
Manganese (Mn, ppm)	52.8	56.4
Iron (Fe, ppm)	69.2	72.8
Copper (Cu, ppm)	4.54	5.36
Boron (B, ppm)	0.82	0.74
Aluminum (Al, ppm)	601.8	695
CEC (meq/ 100g)	11.7	10.24
K/Mg Ratio	0.224	0.226
General Fertility Index (GFI)	71.4	79.6
Percent Base Saturation %K	2.72	4.12
%Mg	12.08	18.24
%Ca	81.14	63.4
%H	3.62	13.66
%Na	0.5	0.54
pH	7.24	5.9
Buffer pH	7	6.88
EC (ms/cm)	0.24	0.222
Saturation %P	14.6	29.8
Saturation %Al	0.1	0.7
Nitrate-N (ppm)	4.6	2.8
Chloride (ppm)	15.4	14
Potential Mineralizable Nitrogen (PMN, ppm)	31.4	32.8
Water Extracted Organic C (ppm)	101.34	93.36
Water Extracted Inorganic N (ppm)	5.822	3.408
Water Extracted Organic N (ppm)	11.714	10.032
Solvita CO2-C (ppm)	47.4	50.8
Reactive C (ppm)	425.6	544.2
Soil Health Index	36.4	40.8
%Microbial Active Carbon (MAC)	47.74	54.62
Organic C:N ratio	8.66	8.98
NRCS Soil Health Calculations	6.9	7.04
Biological Soil Quality	3.8	3.8
Estimated Nitrogen Release (ENR, lb/ac/year)	32	38.4
Water extracted total N	17.6	14
Water extracted Soil Nitrate	5.2	2.8
Water extracted Soil Ammonium	1	1

NRCS soil health calculations based on the Haney test results.

Microbial communities

As shown in Figures 15 (A and B), the bacterial communities of the roots from site A grouped together and site B also grouped together. This indicates that the bacterial communities from site A and B were different, but the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 15B). Similar results were observed for the fungal communities of site A and B (Figure 16). The TRFLP results for field 9 indicated that there are clear differences in the both the bacterial and fungal communities between the 2 sites sampled within the field.

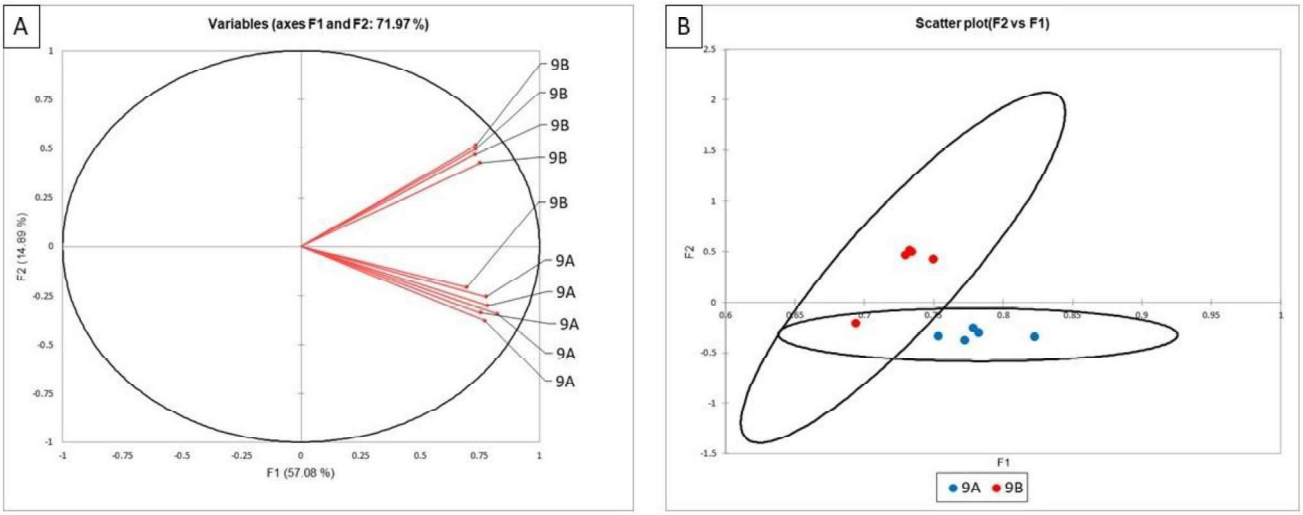

Figure 15. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 9. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

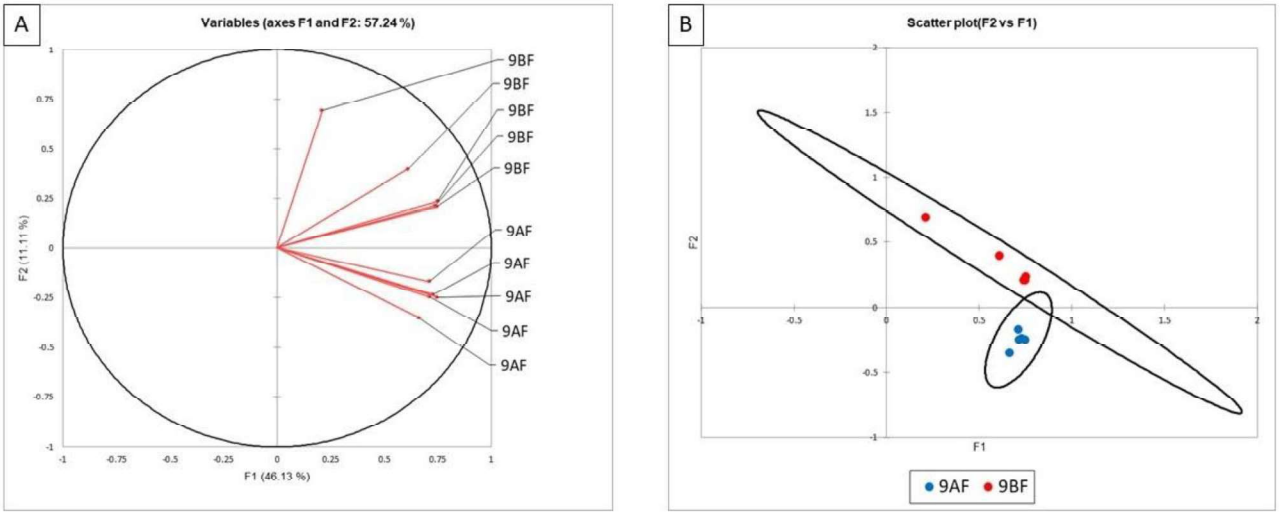

Figure 16. Statistical analysis of TRFLP of the fungal communities in corn roots of field 9. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Summary of Results (Table 10)

- Remote sensing technology (aerial imaging) identified highly productive vs less productive sites at all fields studied (100% success, differences bigger than 5 bu/ac).
- Higher General Fertility index (GFI) and Soil Health Index (SHI) correlated with higher yields on 6 of the 7 fields where yield parameters were available (86% success). The only exception was field # 2 where Site A produced 60.8 bu/ac more than site B, but it had a slightly lower GFI (63.2 vs 66) and SHI (33.8 vs 34.8) than site B. These results can be explained by the low pH of site B (pH 4.82 vs pH 6.06 on site A). Low pH is likely affecting productivity on site B.
- Microbial population differences were reflected in soils with the greatest yield differences.

VitTellus is a Soil Health Test which assesses the chemical, physical and biological balance of the soil, and leads to agronomic strategies to improve soil health which drives greater nutrient utilization, higher crop yields and greater farm profitability. This study provides clear evidence of the site variability in yields that if addressed could help growers produce better crops.

Table 10: Summary of Results

Site	Yield	Differences in bu/ac (field with higher yield)	GFI	SHI
1A	274.2	11.1(B)	70	36.4
1B	285.3		82.6	42.4
2A	196.7	60.8(A)	63.2	33.8
2B	135.9		66	34.8
3A	165.4	12.7(A)	57.8	31.6
3B	152.7		56.4	30.4
4A	136.3	43(A)	72.6	39.2
4B	93.3		67.6	37.4
5A	N/A		67.4	37.2
5B	N/A		64	35.6
6A	205.8	22.2(A)	76	40.6
6B	183.6		61.4	32.2
8A	87.8	52.7(B)	55.4	29.4
8B	140.5		58.2	31.8
9A	187.7	6.1(B)	71.4	36.4
9B	193.8		79.6	40.8

Conclusions

The soil health test gives a complete overview of the chemical status of a soil and allows us to identify the differences between different production areas. It also provides growers with the optimal ranges of those chemical factor that highly correlate with yields and beneficial microbial activities.

Appendix 1

The tables presented below correspond to the summary of the results of the soil chemical analysis.

Field 1: Chemical Analysis

	Report # C20204-10015									
Parameters	1A-1	1A-2	1A-3	1A-4	1A-5	1B-1	1B-2	1B-3	1B-4	1B-5
Yield (bu/ac)	274.2	274.2	274.2	274.2	274.2	285.3	285.3	285.3	285.3	285.3
Organic Matter (OM, %)	2.7	2.6	2.7	2.7	2.7	2.8	2.8	2.8	3	2.9
Phopsphorus (Bicarb, ppm)	47	34	51	49	49	29	39	29	32	36
Phopsphorus (Bray, ppm)	123	82	151	128	129	64	87	76	82	85
Potassium (K, ppm)	70	65	88	84	84	67	92	71	98	101
Magnesium (Mg, ppm)	145	134	151	156	153	134	140	139	135	139
Calcium (Ca, ppm)	1140	1020	1170	1230	1180	1040	1080	1130	1050	1120
Sodium (Na, ppm)	19	18	18	15	13	15	13	15	12	12
Sulfur (S, ppm)	18	16	19	16	15	15	14	14	14	14
Zinc (Zn, ppm)	7.8	6.9	10.3	9.1	8.8	5.4	6.6	6.1	6.3	7.1
Manganese (Mn, ppm)	13	10	13	12	12	8	9	9	10	9
Iron (Fe, ppm)	99	96	98	96	95	91	96	91	95	87
Copper (Cu, ppm)	2.4	2.3	2.4	2.5	2.4	2.5	2.5	2.5	2.5	2.3
Boron (B, ppm)	0.6	0.6	0.7	0.5	0.5	0.6	0.5	0.6	0.5	0.5
Aluminum (Al, ppm)	871	852	847	866	841	869	878	862	869	787
CEC (meq/ 100g)	8.4	7.6	8.6	12.5	8.6	10.1	8	9.4	9.1	9.5
K/Mg Ratio	0.14	0.15	0.18	0.16	0.17	0.15	0.2	0.15	0.23	0.22
General Fertility Index (GFI)	70	70	70	70	70	70	82	80	89	92
Percent Base Saturation %K	2.1	2.2	2.6	1.7	2.5	1.7	2.9	1.9	2.8	2.7
%Mg	14.5	14.6	14.6	10.4	14.8	11	14.5	12.3	12.4	12.3
%Ca	68.2	66.7	68.1	49.1	68.4	51.3	67.1	59.8	57.9	59.2
%H	14.2	15.5	13.8	38.2	13.7	35.4	14.7	25.3	26.3	25.2
%Na	1	1	0.9	0.5	0.7	0.6	0.7	0.7	0.6	0.6
pH	5.4	5.4	5.4	5.4	5.5	5.2	5.6	5.5	5.8	5.8
Buffer pH	6.9	6.9	6.9	6.6	6.9	6.7	6.9	6.8	6.8	6.8
EC (ms/cm)	0.22	0.21	0.22	0.23	0.21	0.2	0.2	0.19	0.19	0.2
Saturation %P	18	12	23	19	20	9	13	11	12	14
Saturation %Al	2.4	2.5	2.2	1.6	1.9	2.7	1.8	1.8	1.2	1
Nitrate-N (ppm)	3	3	3	5	4	3	3	2	3	3
Chloride (ppm)	32	17	15	20	30	12	14	14	17	12
Potential Mineralizable Nitrogen (PMN, ppm)	74	74	78	74	82	70	74	84	80	82
Water Extracted Organic C (ppm)	226	213.4	104.3	157	189.3	226.6	221	218.5	193.7	228.7
Water Extracted Inorganic N (ppm)	5.97	7.1	6.86	6.85	5.57	5.84	7.21	4.74	4.21	7.09
Water Extracted Organic N (ppm)	31.23	23.5	25.94	20.25	26.73	24.16	21.29	27.46	27.09	35.71
Solvita CO2-C (ppm)	62	64	69	64	76	57	62	79	71	76
Reactive C (ppm)	565	533	585	571	575	560	594	619	646	622
Soil Health Index	36	36	37	36	37	35	42	41	46	48
%Microbial Active Carbon (MAC)	27.2	29.9	65.9	40.7	40.4	25.1	27.8	36.2	36.7	33.4
Organic C:N ratio	7.2	9.1	4	7.8	7.1	9.4	10.4	8	7.2	6.4
NRCS Soil Health Calculations	11.5	10.9	8.2	10	12.2	10.4	10.5	12.9	11.7	13.5
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	39	38	39	39	39	0.21	40	40	42	41
Water extracted total N	37	31	33	27	32	30	29	32	31	43
Water extracted Soil Nitrate	3	4	4	5	3	3	5	2	3	4
Water extracted Soil Ammonium	3	3	3	2	2	3	2	2	1	3

Field 2: Chemical Analysis

	Report # C20204-10015									
Parameters	2A-1	2A-2	2A-3	2A-4	2A-5	2B-1	2B-2	2B-3	2B-4	2B-5
Yield (bu/ac)	196.7	196.7	196.7	196.7	196.7	135.9	135.9	135.9	135.9	135.9
Organic Matter (OM, %)	2.9	2.6	2.8	2.6	2.6	3.2	3.4	3	3.1	3
Phopsphorus (Bicarb, ppm)	21	22	21	21	24	24	51	34	34	40
Phopsphorus (Bray, ppm)	42	38	36	28	42	45	90	61	72	85
Potassium (K, ppm)	76	86	97	98	105	111	101	104	102	95
Magnesium (Mg, ppm)	206	266	240	278	272	199	181	184	165	180
Calcium (Ca, ppm)	1210	1410	1390	1520	1550	1210	1200	1130	1160	1130
Sodium (Na, ppm)	14	17	16	19	18	22	23	21	23	25
Sulfur (S, ppm)	8	8	8	8	8	11	11	11	11	11
Zinc (Zn, ppm)	4	4.2	3.6	3.8	4.1	3.8	4.5	3.8	4.1	4.2
Manganese (Mn, ppm)	17	23	18	25	26	15	13	13	14	13
Iron (Fe, ppm)	76	78	68	80	79	105	109	110	103	100
Copper (Cu, ppm)	1.5	1.7	1.5	1.7	1.6	1.4	1.4	1.4	1.5	1.3
Boron (B, ppm)	0.5	0.7	0.6	0.7	0.7	0.6	0.5	0.5	0.4	0.5
Aluminum (Al, ppm)	596	656	576	681	658	865	830	869	829	821
CEC (meq/ 100g)	10.4	10.7	10.4	11.4	11.5	14.1	13.8	19.5	15.9	15.9
K/Mg Ratio	0.12	0.1	0.13	0.11	0.12	0.17	0.17	0.18	0.19	0.16
General Fertility Index (GFI)	69	59	64	60	64	63	72	59	67	69
Percent Base Saturation %K	1.9	2.1	2.4	2.2	2.3	2	1.9	1.4	1.6	1.5
%Mg	16.5	20.7	19.2	20.3	19.7	11.8	10.9	7.9	8.6	9.4
%Ca	58.2	65.7	66.6	66.5	67.2	43	43.3	28.9	36.4	35.6
%H	22.9	10.9	11.2	10.2	10.1	42.5	43.2	61.4	52.7	52.8
%Na	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.6	0.7
pH	5.6	6.1	6	6.3	6.3	4.9	4.7	4.8	4.8	4.9
Buffer pH	6.8	6.9	6.9	6.9	6.9	6.5	6.5	6	6.3	6.3
EC (ms/cm)	0.15	0.16	0.19	0.17	0.19	0.18	0.18	0.18	0.18	0.17
Saturation %P	9	7	8	5	8	7	14	9	11	13
Saturation %Al	1	0.5	0.5	0.3	0.3	3	4.1	2.6	3	2.5
Nitrate-N (ppm)	1	1	5	2	4	2	2	2	2	1
Chloride (ppm)	13	13	17	10	42	15	17	27	23	17
Potential Mineralizable Nitrogen (PMN, ppm)	88	80	84	80	82	84	76	82	84	74
Water Extracted Organic C (ppm)	278.1	251.5	255.6	228.4	219.5	331.8	331.3	342.4	333.8	339.5
Water Extracted Inorganic N (ppm)	4.69	6.99	11.02	6.46	8.62	9.32	7.68	8.49	7.9	9.91
Water Extracted Organic N (ppm)	33.81	29.71	27.58	21.24	24.88	41.48	42.62	29.71	28.1	27.49
Solvita CO2-C (ppm)	86	71	79	71	76	79	66	74	79	64
Reactive C (ppm)	663	636	652	588	603	636	649	658	660	629
Soil Health Index	37	31	35	32	34	34	37	32	36	35
%Microbial Active Carbon (MAC)	30.7	28.2	31	31.1	34.8	23.9	20	21.6	23.7	18.8
Organic C:N ratio	8.2	8.5	9.3	10.8	8.8	8	7.8	11.5	11.9	12.3
NRCS Soil Health Calculations	14.7	12.6	13.2	11.5	12.3	15.4	14.2	13.8	14.1	12.5
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	41	38	40	38	38	44	46	42	43	42
Water extracted total N	39	37	39	28	34	51	50	38	36	37
Water extracted Soil Nitrate	2	3	7	4	6	4	4	4	3	5
Water extracted Soil Ammonium	3	4	4	3	3	6	4	4	5	5

Field 3: Chemical Analysis

	Report # C20204-10015									
Parameters	3A-1	3A-2	3A-3	3A-4	3A-5	3B-1	3B-2	3B-3	3B-4	3B-5
Yield (bu/ac)	165.4	165.4	165.4	165.4	165.4	152.7	152.7	152.7	152.7	152.7
Organic Matter (OM, %)	4.7	4.7	4.5	4.5	4.7	5.2	5.3	5.2	5.1	5.2
Phopsphorus (Bicarb, ppm)	39	44	48	30	38	30	31	17	27	33
Phopsphorus (Bray, ppm)	57	74	71	62	75	50	54	35	49	54
Potassium (K, ppm)	122	132	135	124	168	143	145	146	153	147
Magnesium (Mg, ppm)	570	658	647	615	767	511	548	526	528	537
Calcium (Ca, ppm)	2280	2380	2530	2270	2760	2330	2490	2400	2410	2440
Sodium (Na, ppm)	21	22	21	20	25	19	21	22	21	24
Sulfur (S, ppm)	10	11	11	11	11	10	11	10	11	11
Zinc (Zn, ppm)	5.9	6.9	6.2	5.2	5.8	4.4	4.5	3.8	4	3.7
Manganese (Mn, ppm)	13	12	11	11	15	4	4	4	5	4
Iron (Fe, ppm)	89	99	97	88	105	123	123	128	129	127
Copper (Cu, ppm)	2.1	2.4	2.1	1.9	2.4	2.7	2.7	2.7	2.7	2.6
Boron (B, ppm)	0.5	0.5	0.5	0.4	0.6	0.5	0.5	0.5	0.5	0.5
Aluminum (Al, ppm)	798	826	872	766	970	933	912	1000	1005	1003
CEC (meq/ 100g)	17.7	18.9	19.6	18	21.8	24.7	28.2	24	25.3	27.9
K/Mg Ratio	0.07	0.06	0.07	0.06	0.07	0.09	0.08	0.09	0.09	0.09
General Fertility Index (GFI)	60	57	57	58	57	57	56	58	56	55
Percent Base Saturation %K	1.8	1.8	1.8	1.8	2	1.5	1.3	1.6	1.6	1.4
%Mg	26.8	28.9	27.5	28.5	29.3	17.2	16.2	18.3	17.4	16
%Ca	64.4	62.8	64.5	63	63.2	47.2	44.1	50	47.7	43.7
%H	6.4	6	5.8	6.3	5.1	33.8	38.1	29.8	33	38.5
%Na	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.4	0.4	0.4
pH	6.9	6.9	6.5	6.7	6.8	5.5	5.5	5.6	5.7	5.7
Buffer pH	6.9	6.9	6.9	6.9	6.9	6.3	6.1	6.4	6.3	6.1
EC (ms/cm)	0.22	0.22	0.3	0.25	0.25	0.21	0.27	0.21	0.25	0.27
Saturation %P	9	11	10	10	10	7	8	5	6	7
Saturation %Al	0.1	0.1	0.2	0.1	0.1	0.7	0.6	0.7	0.6	0.5
Nitrate-N (ppm)	3	2	12	7	5	2	9	2	6	8
Chloride (ppm)	8	8	7	8	13	6	6	9	8	6
Potential Mineralizable Nitrogen (PMN, ppm)	45	45	41	42	44	35	41	41	40	41
Water Extracted Organic C (ppm)	256.3	253.5	247.7	278.2	262.9	319.8	282.2	307.4	303.7	309.4
Water Extracted Inorganic N (ppm)	11.9	7.53	16.17	15.35	9.143	8.97	16.09	10.48	17.71	15.99
Water Extracted Organic N (ppm)	41	39.17	36.13	29.75	19.657	22.33	23.11	26.32	26.69	28.51
Solvita CO2-C (ppm)	89	93	76	79	86	57	76	74	71	74
Reactive C (ppm)	819	838	819	796	854	824	806	774	807	803
Soil Health Index	33	32	31	31	31	30	31	31	30	30
%Microbial Active Carbon (MAC)	34.9	36.5	30.8	28.5	32.5	17.8	27.1	24.1	23.4	23.9
Organic C:N ratio	6.3	6.5	6.9	9.4	13.4	14.3	12.2	10.9	11.4	10.9
NRCS Soil Health Calculations	45.6	15.7	13.7	13.7	13.1	11.1	12.8	13.3	12.8	13.3
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	60	60	57	57	60	65	66	65	64	65
Water extracted total N	53	47	52	45	29	31	39	39	44	45
Water extracted Soil Nitrate	8	6	14	13	7	6	13	7	14	14
Water extracted Soil Ammonium	3	2	3	3	2	3	3	3	4	2

Field 4: Chemical Analysis

	Report # C20204-10015									
Parameters	4A-1	4A-2	4A-3	4A-4	4A-5	4B-1	4B-2	4B-3	4B-4	4B-5
Yield (bu/ac)	136.3	136.3	136.3	136.3	136.3	93.3	93.3	93.3	93.3	93.3
Organic Matter (OM, %)	3.5	3.6	3.4	3.2	3.5	4	4	3.8	3.9	3.8
Phopsphorus (Bicarb, ppm)	36	35	38	38	43	33	38	49	53	56
Phopsphorus (Bray, ppm)	72	80	90	75	86	75	86	82	90	112
Potassium (K, ppm)	95	110	100	107	105	120	124	134	131	143
Magnesium (Mg, ppm)	202	212	200	195	185	233	249	277	262	273
Calcium (Ca, ppm)	2370	2630	2370	2620	3080	3210	3260	3930	3470	3470
Sodium (Na, ppm)	18	25	25	28	24	27	27	28	28	29
Sulfur (S, ppm)	9	9	10	9	10	10	10	11	10	12
Zinc (Zn, ppm)	18.1	22.8	19.3	17.8	20.9	13	12.3	20.2	14.6	13.4
Manganese (Mn, ppm)	186	232	193	206	199	106	90	88	86	92
Iron (Fe, ppm)	64	67	64	66	62	62	65	66	66	71
Copper (Cu, ppm)	6.7	8.2	7	6.6	6.9	5.5	5.5	5.4	5.7	5.9
Boron (B, ppm)	0.7	0.8	0.8	0.7	0.7	0.8	0.8	0.9	0.9	1
Aluminum (Al, ppm)	552	667	580	645	520	537	581	567	591	669
CEC (meq/ 100g)	15.9	17.6	15.1	17.4	18.5	20.2	20.7	22.4	20	20.1
K/Mg Ratio	0.14	0.16	0.15	0.17	0.18	0.16	0.15	0.15	0.16	0.16
General Fertility Index (GFI)	72	78	69	77	67	75	73	64	65	61
Percent Base Saturation %K	1.5	1.6	1.7	1.6	1.5	1.5	1.5	1.5	1.7	1.8
%Mg	10.6	10.1	11.1	9.4	8.3	9.6	10	10.3	10.9	11.3
%Ca	74.5	74.8	78.7	75.4	83.3	79.3	78.9	87.7	86.9	86.4
%H	12.9	12.9	7.8	12.9	6.4	9	9	0	0	0
%Na	0.5	0.6	0.7	0.7	0.6	0.6	0.6	0.5	0.6	0.6
pH	7	7	6.8	7	6.7	7.1	7.1	7.3	7.4	7.4
Buffer pH	7	7	6.9	7	6.9	7	7	7	7	7
EC (ms/cm)	0.38	0.38	0.39	0.54	0.46	0.26	0.3	0.47	0.34	0.28
Saturation %P	17	15	7	15	7	6	7	6	7	8
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0
Nitrate-N (ppm)	25	24	26	45	32	5	9	28	14	4
Chloride (ppm)	11	13	11	11	13	12	13	9	12	11
Potential Mineralizable Nitrogen (PMN, ppm)	46	47	42	50	45	46	54	45	47	45
Water Extracted Organic C (ppm)	167.6	157.3	150.7	141.3	152.3	204.2	231.5	191	195.6	227.3
Water Extracted Inorganic N (ppm)	30.95	28.65	29.66	53.27	34.59	12.81	11.41	30.15	15.83	20.55
Water Extracted Organic N (ppm)	23.85	21.35	26.65	34.83	23.51	33.79	36.29	32.95	19.57	29.15
Solvita CO2-C (ppm)	96	99	79	115	89	96	143	93	99	93
Reactive C (ppm)	668	682	72	606	676	747	779	757	782	759
Soil Health Index	39	42	37	42	36	40	42	35	36	34
%Microbial Active Carbon (MAC)	57.1	62.9	52.6	81.4	58.7	46.9	61.8	48.5	50.6	40.7
Organic C:N ratio	7	7.4	5.7	4.1	6.5	6	6.4	5.8	10	7.8
NRCS Soil Health Calculations	13.6	13.6	12.1	13.3	12.6	15	20.2	14.5	13.8	14.4
Biological Soil Quality	4	4	4	5	4	4	5	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	47	48	46	44	47	52	52	50	51	50
Water extracted total N	55	50	56	88	58	47	48	63	35	50
Water extracted Soil Nitrate	30	25	28	51	32	11	11	30	16	18
Water extracted Soil Ammonium	1	4	2	3	2	2	1	0	0	2

Field 5: Chemical Analysis

	Report # C20204-10015									
Parameters	5A-1	5A-2	5A-3	5A-4	5A-5	5B-1	5B-2	5B-3	5B-4	5B-5
Yield (bu/ac)										
Organic Matter (OM, %)	5.2	5.3	5.2	5.4	5.2	5.5	5.5	5.6	5.7	5.4
Phopsphorus (Bicarb, ppm)	28	32	32	38	32	81	89	85	85	81
Phopsphorus (Bray, ppm)	49	59	59	67	63	205	239	208	208	200
Potassium (K, ppm)	183	216	209	173	223	481	588	529	441	506
Magnesium (Mg, ppm)	482	529	534	485	566	593	666	590	508	553
Calcium (Ca, ppm)	2820	3130	3170	2710	3190	2460	2780	2610	2230	2340
Sodium (Na, ppm)	16	16	16	15	19	31	40	35	31	34
Sulfur (S, ppm)	7	8	8	7	8	23	29	25	21	18
Zinc (Zn, ppm)	6.1	9	12.3	7.7	6.8	77	80.2	70	65.7	68.5
Manganese (Mn, ppm)	85	91	89	78	92	24	25	21	19	20
Iron (Fe, ppm)	84	93	92	91	98	125	136	126	118	131
Copper (Cu, ppm)	2.5	2.6	2.6	2.3	2.7	2.5	2.7	2.5	2.3	2.4
Boron (B, ppm)	0.8	0.9	0.9	0.7	0.9	1.1	1.1	1.1	0.9	1
Aluminum (Al, ppm)	676	743	729	673	782	672	697	653	574	688
CEC (meq/ 100g)	20.5	21.8	22	19.2	22.5	21.3	24.2	19.4	17.4	18.6
K/Mg Ratio	0.12	0.12	0.12	0.11	0.12	0.25	0.27	0.28	0.27	0.28
General Fertility Index (GFI)	71	66	68	64	68	70	68	58	62	62
Percent Base Saturation %K	2.3	2.5	2.4	2.3	2.5	5.8	6.2	7	6.5	7
%Mg	19.6	20.2	20.2	21	21	23.2	22.9	25.3	24.3	24.8
%Ca	68.9	71.7	71.9	70.4	71	57.7	57.4	67.2	64	63
%H	8.8	5.2	5.2	6	5.1	12.7	12.7	0	4.4	4.4
%Na	0.3	0.3	0.3	0.3	0.4	0.6	0.7	0.8	0.8	0.8
pH	7.1	6.9	6.9	6.9	6.8	7	7	7.3	7.2	7.2
Buffer pH	7	6.9	6.9	6.9	6.9	7	7	7	7	7
EC (ms/cm)	0.21	0.21	0.28	0.2	0.22	0.28	0.32	0.29	0.26	0.29
Saturation %P	9	10	10	13	10	39	44	41	46	37
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0.1
Nitrate-N (ppm)	2	1	10	2	2	2	3	2	2	7
Chloride (ppm)	7	9	7	8	7	17	13	14	12	167
Potential Mineralizable Nitrogen (PMN, ppm)	45	48	44	48	48	34	45	45	45	43
Water Extracted Organic C (ppm)	216.6	238.1	220.2	253.8	208	322.5	317	288.5	281.3	283.6
Water Extracted Inorganic N (ppm)	4.24	1.3	19.79	3.8	4.28	5.47	7.13	4.5	3.87	4.35
Water Extracted Organic N (ppm)	19.06	19.3	18.51	24.3	24.32	25.73	27.97	25.6	27.23	29.85
Solvita CO2-C (ppm)	89	105	86	105	102	53	93	89	93	82
Reactive C (ppm)	771	779	733	783	786	1039	1075	1106	1094	1078
Soil Health Index	38	37	37	36	38	37	38	33	35	35
%Microbial Active Carbon (MAC)	41.3	44.1	38.8	41.4	49	16.5	29.2	31	32.9	29
Organic C:N ratio	11.4	12.3	11.9	10.4	8.6	12.5	11.3	11.3	10.3	9.5
NRCS Soil Health Calculations	13	14.8	12.6	15.5	14.7	11.1	15.2	14.4	14.8	14.4
Biological Soil Quality	4	5	4	5	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	65	66	65	67	65	68	68	69	70	67
Water extracted total N	23	21	35	28	29	31	35	30	31	34
Water extracted Soil Nitrate	3	1	16	3	3	3	3	3	3	3
Water extracted Soil Ammonium	1	0	1	1	1	3	3	1	1	1

Field 6: Chemical Analysis

	Report # C20204-10015									
Parameters	6A-1	6A-2	6A-3	6A-4	6A-5	6B-1	6B-2	6B-3	6B-4	6B-5
Yield (bu/ac)	205.8	205.8	205.8	205.8	205.8	183.6	183.6	183.6	183.6	183.6
Organic Matter (OM, %)	2.9	2.7	2.8	2.8	2.8	2.2	2.3	2.3	2.2	2.3
Phopsphorus (Bicarb, ppm)	32	24	26	28	28	69	41	62	45	50
Phopsphorus (Bray, ppm)	79	60	52	56	54	180	69	145	87	82
Potassium (K, ppm)	189	137	126	145	124	125	112	112	118	127
Magnesium (Mg, ppm)	215	210	207	218	211	160	142	128	156	148
Calcium (Ca, ppm)	1180	1280	1200	1260	1310	3460	3410	3070	3590	3440
Sodium (Na, ppm)	13	10	10	9	11	24	12	12	11	13
Sulfur (S, ppm)	14	10	14	8	8	18	21	13	14	13
Zinc (Zn, ppm)	5.6	4.9	7.5	4.9	4.6	9.4	5.9	9.9	6.6	12.5
Manganese (Mn, ppm)	42	48	46	46	48	90	89	68	107	99
Iron (Fe, ppm)	68	64	62	64	64	50	47	47	50	50
Copper (Cu, ppm)	3.2	3.4	3.3	3.5	3.3	3.3	3.3	3.1	3.7	3.5
Boron (B, ppm)	0.7	0.7	0.8	0.7	0.7	1.3	0.9	0.9	0.9	0.9
Aluminum (Al, ppm)	670	635	631	680	631	306	303	251	318	285
CEC (meq/ 100g)	9.4	9.7	9.3	9.7	9.9	19	18.6	16.7	19.6	18.8
K/Mg Ratio	0.27	0.2	0.19	0.2	0.18	0.24	0.23	0.27	0.23	0.26
General Fertility Index (GFI)	82	78	73	77	70	59	62	59	62	65
Percent Base Saturation %K	5.2	3.6	3.5	3.8	3.2	1.7	1.5	1.7	1.5	1.7
%Mg	19	18	18.6	18.7	17.8	7	6.4	6.4	6.6	6.6
%Ca	62.7	65.8	64.7	64.9	66.5	90.9	91.9	91.7	91.7	91.5
%H	12.5	12.1	12.7	12.1	11.9	0	0	0	0	0
%Na	0.6	0.4	0.5	0.4	0.5	0.5	0.3	0.3	0.2	0.3
pH	6.2	6.4	6.5	6.2	6.7	7.7	7.7	7.7	8	7.7
Buffer pH	6.9	6.9	6.9	6.9	6.9	7	7	7	7	7
EC (ms/cm)	0.23	0.18	0.19	0.17	0.17	0.29	0.3	0.25	0.27	0.26
Saturation %P	15	12	10	10	11	13	5	10	6	6
Saturation %Al	0.5	0.3	0.3	0.5	0.2	0	0	0	0	0
Nitrate-N (ppm)	7	3	2	3	3	2	3	2	2	2
Chloride (ppm)	41	25	19	18	18	24	14	13	14	13
Potential Mineralizable Nitrogen (PMN, ppm)	52	41	39	36	41	33	31	36	30	33
Water Extracted Organic C (ppm)	151.9	113.6	121.7	101.9	115.8	94.78	103	106.3	96.6	103.5
Water Extracted Inorganic N (ppm)	10.33	4.23	3.66	5	5.48	5.08	5.61	3.47	3.5	3.52
Water Extracted Organic N (ppm)	12.74	13.21	11.62	13.42	12.84	8.77	12.83	10.82	9.92	10.84
Solvita CO2-C (ppm)	127	76	69	59	74	51	46	59	44	51
Reactive C (ppm)	735	721	739	704	762	583	598	612	403	531
Soil Health Index	47	41	38	40	37	31	32	32	32	34
%Microbial Active Carbon (MAC)	83.6	67.3	56.5	58.1	63.9	54.2	44.2	55.5	45.4	49.7
Organic C:N ratio	11.9	8.6	10.5	7.6	9	10.8	8	9.8	9.7	9.5
NRCS Soil Health Calculations	15.5	10.1	9.2	8.3	9.6	7	6.9	8	6.3	7.3
Biological Soil Quality	5	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	41	39	40	40	40	34	35	35	34	35
Water extracted total N	23	17	15	18	18	14	18	14	13	14
Water extracted Soil Nitrate	10	4	3	5	4	4	4	3	3	3
Water extracted Soil Ammonium	1	1	1	1	1	1	2	1	1	1

Field 8: Chemical Analysis

	Report # C20204-10015									
Parameters	8A-1	8A-2	8A-3	8A-4	8A-5	8B-1	8B-2	8B-3	8B-4	8B-5
Yield (bu/ac)	87.8	87.8	87.8	87.8	87.8	140.5	140.5	140.5	140.5	140.5
Organic Matter (OM, %)	3.4	3.2	3.2	3.2	3.1	3	3.1	3.1	3.2	3.2
Phopsphorus (Bicarb, ppm)	8	5	7	5	6	10	21	8	13	13
Phopsphorus (Bray, ppm)	13	7	11	7	8	13	40	12	17	23
Potassium (K, ppm)	115	105	116	107	111	107	127	98	111	132
Magnesium (Mg, ppm)	247	266	251	264	260	264	287	256	270	285
Calcium (Ca, ppm)	2190	2150	2020	2220	2140	1720	1920	1770	1940	1870
Sodium (Na, ppm)	12	14	13	15	14	14	16	13	15	17
Sulfur (S, ppm)	8	8	7	8	8	7	12	8	11	8
Zinc (Zn, ppm)	2	1.5	1.8	1.6	1.7	2.6	6.6	2.4	3	2.8
Manganese (Mn, ppm)	8	3	3	4	4	3	3	3	4	4
Iron (Fe, ppm)	76	76	78	78	80	82	88	75	83	85
Copper (Cu, ppm)	2	2	2	2.1	2.1	1.5	1.9	1.6	1.7	1.7
Boron (B, ppm)	0.9	0.8	0.9	1	1	0.9	1.1	0.9	1	1
Aluminum (Al, ppm)	747	796	780	787	803	727	740	659	735	735
CEC (meq/ 100g)	14.5	14.5	13.7	14.8	14.4	12.3	13.6	12.5	13.5	13.3
K/Mg Ratio	0.14	0.12	0.14	0.13	0.13	0.12	0.14	0.12	0.13	0.14
General Fertility Index (GFI)	57	54	57	54	55	56	62	56	57	60
Percent Base Saturation %K	2	1.9	2.2	1.9	2	2.2	2.4	2	2.1	2.5
%Mg	14.2	15.3	15.2	14.9	15.1	17.9	17.6	17.1	16.7	17.8
%Ca	75.4	74.3	73.6	74.9	74.4	69.9	70.8	71	72	70.3
%H	8.1	8.1	8.5	7.9	8.1	9.5	8.6	9.4	8.7	8.8
%Na	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6
pH	6.7	6.3	6.5	6.4	6.5	5.9	5.8	6.4	6.5	6.1
Buffer pH	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
EC (ms/cm)	0.18	0.18	0.18	0.19	0.18	0.17	0.21	0.18	0.19	0.18
Saturation %P	2	1	2	1	1	2	7	2	3	4
Saturation %Al	0.2	0.3	0.2	0.3	0.2	0.6	0.7	0.3	0.2	0.4
Nitrate-N (ppm)	1	1	2	2	1	2	2	2	1	2
Chloride (ppm)	17	13	15	11	12	17	18	14	16	20
Potential Mineralizable Nitrogen (PMN, ppm)	48	26	37	345	31	43	38	44	41	43
Water Extracted Organic C (ppm)	175.4	186.1	149.2	169.2	203.3	172.6	204.2	199	176	198.4
Water Extracted Inorganic N (ppm)	3.62	4.19	5.43	3.57	4.79	4.81	7.21	5.63	5.35	4.65
Water Extracted Organic N (ppm)	13.85	16.07	13.26	15.44	15.63	16.34	17.89	19.07	14.55	18.55
Solvita CO2-C (ppm)	105	35	64	55	46	82	66	86	76	82
Reactive C (ppm)	583	529	542	571	565	542	583	3	642	601
Soil Health Index	33	27	30	29	28	31	33	31	31	33
%Microbial Active Carbon (MAC)	59.9	19	42.8	32.5	22.4	47.7	32.5	43	43.4	41.5
Organic C:N ratio	12.7	11.6	11.3	11	13	10.6	11.4	10.4	12.1	10.7
NRCS Soil Health Calculations	13.6	7	9.2	8.7	8.1	11.6	10.5	12.4	10.9	12.1
Biological Soil Quality	5	3	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	46	44	44	44	43	42	43	43	44	44
Water extracted total N	17	20	19	19	20	21	25	25	20	23
Water extracted Soil Nitrate	3	3	4	3	3	3	5	4	3	3
Water extracted Soil Ammonium	1	1	1	1	1	1	2	1	2	1

Field 9: Chemical Analysis

	Report # C20204-10015									
Parameters	9A-1	9A-2	9A-3	9A-4	9A-5	9B-1	9B-2	9B-3	9B-4	9B-5
Yield (bu/ac)	187.7	187.7	187.7	187.7	187.7	193.8	193.8	193.8	193.8	193.8
Organic Matter (OM, %)	2.1	2.1	2	1.8	2	2.6	2.7	2.6	2.7	2.6
Phopsphorus (Bicarb, ppm)	56	55	58	45	67	61	64	61	55	58
Phopsphorus (Bray, ppm)	142	149	151	111	145	171	170	156	155	157
Potassium (K, ppm)	122	129	124	109	136	172	147	177	179	151
Magnesium (Mg, ppm)	176	168	164	168	169	222	220	230	224	224
Calcium (Ca, ppm)	1730	1910	2010	2080	1770	1290	1260	1320	1290	1330
Sodium (Na, ppm)	12	14	14	13	14	12	12	14	14	12
Sulfur (S, ppm)	22	16	16	11	14	18	23	18	16	20
Zinc (Zn, ppm)	14.1	10.3	10	7	14.9	12.8	12.2	9	16.9	14
Manganese (Mn, ppm)	52	53	54	54	51	52	54	61	58	57
Iron (Fe, ppm)	71	71	70	66	68	73	74	73	71	73
Copper (Cu, ppm)	4.4	4.5	4.7	4.5	4.6	5.5	5.1	5.2	5.5	5.5
Boron (B, ppm)	0.8	0.8	0.9	0.8	0.8	0.7	0.7	0.8	0.8	0.7
Aluminum (Al, ppm)	610	601	599	598	601	686	693	704	688	704
CEC (meq/ 100g)	11.5	11.3	12.4	12.1	11.2	10	10.9	10.2	10	10.1
K/Mg Ratio	0.21	0.23	0.23	0.2	0.25	0.24	0.2	0.23	0.25	0.21
General Fertility Index (GFI)	73	68	73	71	72	79	82	80	80	77
Percent Base Saturation %K	2.7	2.9	2.6	2.3	3.1	4.4	3.4	4.4	4.6	3.8
%Mg	12.7	12.4	11.1	11.6	12.6	18.6	16.8	18.8	18.6	18.4
%Ca	75.2	84.3	81.3	85.8	79.1	64.7	57.6	64.7	64.4	65.6
%H	8.9	0	4.6	0	4.6	11.8	21.7	11.5	11.7	11.6
%Na	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5
pH	7.1	7.3	7.2	7.4	7.2	5.9	5.7	6	5.9	6
Buffer pH	7	7	7	7	7	6.9	6.8	6.9	6.9	6.9
EC (ms/cm)	0.27	0.24	0.24	0.21	0.24	0.21	0.23	0.21	0.22	0.24
Saturation %P	30	11	12	8	12	32	31	28	29	29
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0.7	0.9	0.6	0.7	0.6
Nitrate-N (ppm)	6	4	4	3	6	2	2	2	4	4
Chloride (ppm)	16	12	16	17	16	17	13	14	14	12
Potential Mineralizable Nitrogen (PMN, ppm)	35	32	31	27	32	31	36	33	35	29
Water Extracted Organic C (ppm)	119.4	111.9	112.8	90	72.6	102.3	94.5	91.5	90.1	88.4
Water Extracted Inorganic N (ppm)	7.76	5.34	5.66	3.93	6.42	2.48	2.51	3.07	4.76	4.22
Water Extracted Organic N (ppm)	14.42	12.36	12.64	9.67	9.48	10.02	9.79	10.43	10.44	9.48
Solvita CO2-C (ppm)	57	48	46	38	48	46	59	51	57	41
Reactive C (ppm)	455	474	360	406	433	549	520	542	568	542
Soil Health Index	38	35	37	35	37	40	42	41	42	39
%Microbial Active Carbon (MAC)	47.6	42.7	40.3	42.3	65.8	44.5	62.6	56.5	63	46.5
Organic C:N ratio	8.3	9.1	8.9	9.3	7.7	8.5	9.7	8.8	8.6	9.3
NRCS Soil Health Calculations	8.3	7.1	6.9	5.7	6.5	6.8	7.8	7.1	7.6	5.9
Biological Soil Quality	4	4	4	3	4	4	4	4	4	3
Estimated Nitrogen Release (ENR, lb/ac/year)	33	33	32	30	32	38	39	38	39	38
Water extracted total N	22	18	18	14	16	15	12	14	15	14
Water extracted Soil Nitrate	7	5	5	3	6	2	2	2	4	4
Water extracted Soil Ammonium	1	1	1	1	1	1	1	1	1	1

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2021 - Soil Health Analysis of Corn Fields- Final report

Client name	Date
St. Clair Region Soil and Crop Improvement Association 2018-2020 Tier 2 Project	December 15th, 2021

The **objective** of this work is to test how the A&L laboratories' VitTellus soil health analysis corelates with the yield and plant performance of corn in Ontario.

Methods

A&L received 30 corn roots with their respective root ball soil for analysis. These samples were collected by OMAFRA, Ridgetown office from three corn fields in South-Western Ontario. Five plants were sample from each site based on NDVI maps identifying the locations as producing high yields or low producing areas for a total of 10 plants per field. The roots with their attached soil were code labelled, packaged individually, and sent to A&L for analysis (Table 1).

Table 1. List of samples received for analysis

Field	Samples	Samples
1	1A-1 to 5	1B-1 to 5
2	2A-1 to 5	2B-1 to 5
3	3A-1 to 5	3B-1 to 5

Upon receiving the samples, the soil was separated from the roots and sent for the VitTellus soil health analysis. A total of 30 soil samples were analysed. The roots from all 3 fields were washed with tap water, chopped into small pieces, and their DNA was extracted. The DNA was used to compare the root microbial communities (bacteria and fungi) of plants from the two areas within each field.

Soil Health Analysis: The VitTellus soil health uses the chemical parameters of the soil and some biological properties to calculate a relative Soil Health Index (SHI). This index ranges from 0 to 60, and the health of the soil is ranked as follow:

- SHI 0 – 20: very low soil health,
- SHI 20 – 30: low soil health,

- SHI 30 – 40: mediocre soil health,
- SHI 40 – 50: good soil health, and
- SHI 50 – 60: very good soil health

The VitTellus soil health test provides growers with an optimal range for crop productivity of chemical factors that our research has shown to be directly correlated with yield and those microbial activities favourable to plant health.

Analysis of the microbial communities: The root's microbial populations were analysed by Terminal Restriction Fragment Length Polymorphism (TRFLP). TRFLP is a fingerprinting technique for monitoring composition of microbial communities and it can be used to track spatial and temporal shifts in microbial populations. Briefly, a conserved region of DNA extracted from roots (16S rRNA gene for bacteria and ITS gene for fungi) were amplified with fluorescently labeled primers. The fluorescent PCR products were then digested with a restriction enzyme. The size and quantity of the fragments were determined using capillary electrophoresis. The banding pattern obtained provides a fingerprint of the microbial community. The relationship of such fingerprints to one another was identified using a multivariate statistical technique called Principle Component Analysis (PCA). Principle Components (PC) are statistical values generated to best explain the variation in a set of samples. TRFLP data were transformed into binary data (is a specific peak present (1) or not (0)) before performing PCA. PCA analysis clustered the data based on similarity of peak presence; 95% confidence intervals were automatically drawn around each sample group. Groups that do not overlap are considered statistically different in their microbial community.

Yield: Yields were determined by OMAFRA, Ridgetown by hand harvesting the same areas from where the mid season samples were collected. Final yields were kindly provided to us by Anne Verhallen, Soil Management Specialist (Horticultural Crops), Ontario Ministry of Agriculture, Food and Rural Affairs, Ridgetown, Ontario.

Results

Field 1

Site B produced 19.5 bu/ac more than site A (site B: 249.2 bu/ac vs. site A 229.7 bu/ac). A summary of the soil chemical analysis and yield of field 1 is presented in Table 2 (raw data can be found in the appendix).

Both sites in this field had very similar soil chemistry. Both sites had good levels of organic matter (3.54 and 4.06), a good GFI (67.4 and 64.4), moderate SHI (35.6 and 34.2), ideal biological soil quality (4), high levels of reactive carbon (750.8 and 752), and good soil pH (pH 6.74 and 6.82).

Both sites had high levels of magnesium (289.6 and 337 ppm) and low K/Mg ratios (0.162 and 0.12). Our previous research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. Potash application should benefit the productivity at both sites.

Site B had slightly higher levels organic matter (4.06 vs 3.54), higher Solvita CO2-C (76ppm vs 67ppm) and slightly higher % microbial active carbon (60.5 vs 53.92). Solvita CO2-C measures the microbial activity in the soil and highly related to soil fertility. The differences in these parameters may have provided a yield benefit to this site.

Overall, the chemical profiles of the two soils are remarkably similar and the yield differences were not likely statistically significant.

Table 2. Soil Analysis of Field 1.

Parameters	1A	1B
Yield (bu/ac)	229.7	249.2
Organic Matter (OM, %)	3.54	4.06
Phopsphorus (Bicarb, ppm)	31.2	33.2
Phopsphorus (Bray, ppm)	54.4	59
Potassium (K, ppm)	151	135
Magnesium (Mg, ppm)	289.6	337
Calcium (Ca, ppm)	1870	2104
Sodium (Na, ppm)	14	15.2
Sulfur (S, ppm)	7.6	7.6
Zinc (Zn, ppm)	4.34	4.46
Manganese (Mn, ppm)	14.2	6
Iron (Fe, ppm)	73.6	81.2
Copper (Cu, ppm)	2.48	3.66
Boron (B, ppm)	0.5	0.6
Aluminum (Al, ppm)	729	804.4
CEC (meq/ 100g)	13.4	14.92
K/Mg Ratio	0.162	0.12
General Fertility Index (GFI)	67.4	64.4
Percent Base Saturation %K	2.9	2.28
%Mg	18.04	18.84
%Ca	69.88	70.58
%H	8.74	7.82
%Na	0.44	0.42
pH	6.74	6.82
Buffer pH	6.9	6.9
EC (ms/cm)	0.2	0.202
Saturation %P	9.6	9.4
Saturation %Al	0.16	0.1
Nitrate-N (ppm)	5	4
Chloride (ppm)	9.8	8.6
Potential Mineralizable Nitrogen (PMN, ppm)	38.2	41
Solvita CO2-C (ppm)	67	76
Reactive C (ppm)	750.8	752
Soil Health Index	35.6	34.2
%Microbial Active Carbon (MAC)	53.92	60.5
NRCS Soil Health Calculations	7.88	8.82
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	76.4	82

NRCS soil health calculations based on the Haney test results

Microbial communities

The composition of the bacterial and fungal communities of roots from sites A and B were analysed using TRFLP. We compared the microbial communities from both sites and summarized the results in two different ways: **(A) As vectors:** Figures 1A and 2A show each TRFLP result as a vector (bacterial and fungal, respectively). Each vector represents the community of one plant (named 1- 5). The closer the vectors are to each other, the more similar are the populations they represent. **(B) As single data point:** To visualize if there were any statistically significant differences between the communities from site A and B, we summarized our results as single data points and plotted them two dimensionally (Figures 1B and 2B). The degree of separation between dots indicates the extent of similarities or differences. The further the dots are separated, the greater the difference. The closer they are, the more similar the population. Confidence circles (95%) that do not overlap are considered significantly different.

No differences in the bacterial communities of roots from site A and B were found (Figure 1A and B). All samples clustered together indicating that their bacterial communities were similar.

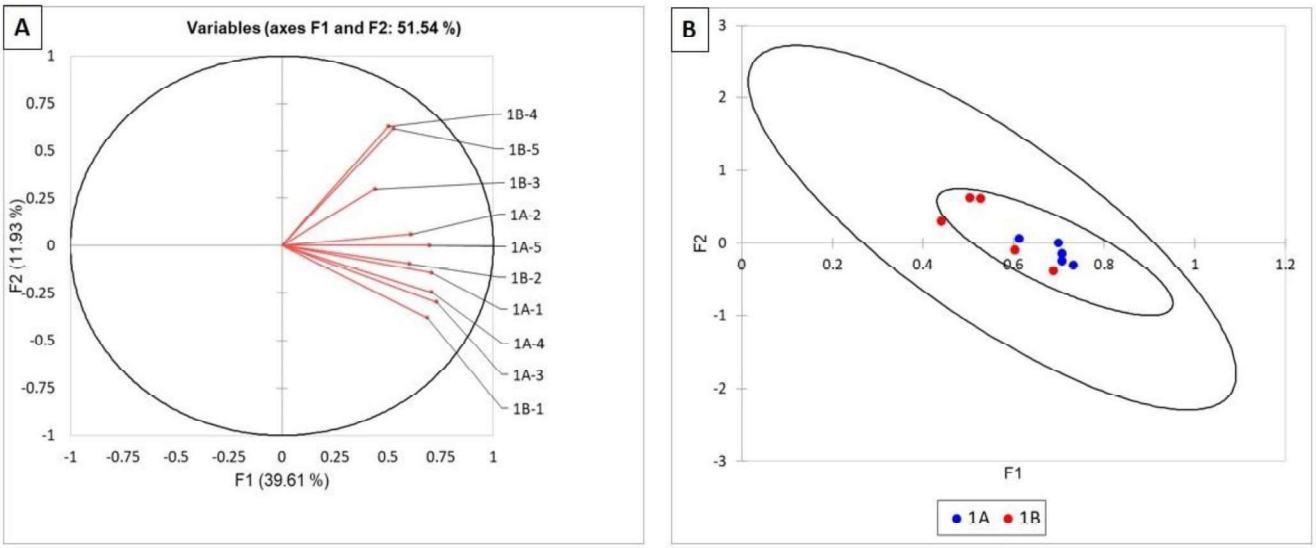

Figure 1. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 1. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

As shown on Figure 2A, the vectors of the fungal communities of the roots from site A were all grouped below the 0 line whereas those from site B were all above. The cluster analysis grouped all the A components close to each other and the B components samples were also closely related (Figure 1B, data as single points). This indicates that the fungal communities from site A and B were different, but the differences were not statistically valid as indicated by the overlapping confidence circles (Figure 2B). At the same time this is indicative of that some clear differences in the fungal communities exist at the two locations.

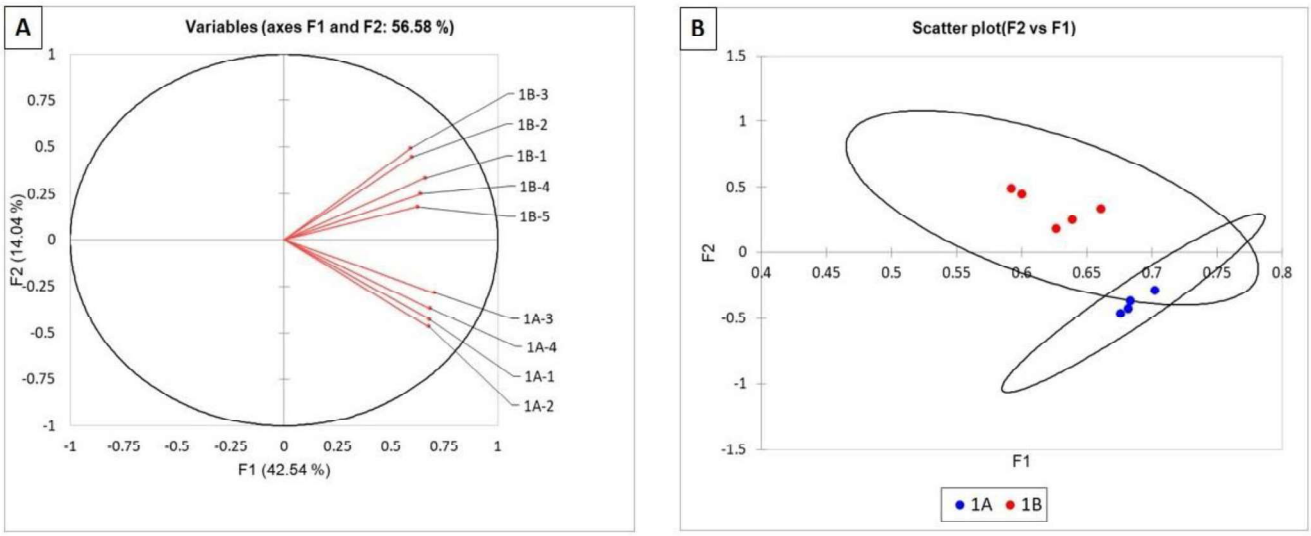

Figure 2. Statistical analysis of TRFLP of the fungal communities in corn roots of field 1. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 2

Site B produced 108.2 bu/ac more than site A (site B: 311.3 bu/ac vs. site A 203.1 bu/ac). A summary of the soil chemical analysis and yield of field 2 is presented in Table 3.

In this field site B had a higher organic matter content (2.18% vs. 1.72%), phosphorus (Bicarb 92.2 ppm vs. 45.4 ppm; Bray 278 ppm vs. 99.8 ppm), potassium (120.4 ppm vs. 87.8 ppm), percent saturation potassium (4.68% vs. 2.16%) and percent saturation magnesium (17.12% vs. 8.3%). For this soil type, the percent saturation of potassium in site B falls above the ideal range while site A is below the ideal range. Similarly, site B had a good level of phosphorus while site A had mediocre levels. The percent saturation magnesium for site B fell within the ideal range for this soil type whereas site A fell below the ideal range. Our previous research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. In this field, site B had K:Mg ratios that fell withing the ideal range and site A had K/Mg ratios that were higher than the ideal range. Any deviations from the ideal K:Mg range either lower or higher can have negative impacts on crop productivity.

Site B had a higher GFI (81 vs. 65) and SHI (42.6 vs. 34.2) than site A. The general fertility index (GFI) is a calculation of field fertility based on soil nutrient levels and soil type. It is strongly correlated to yield, field performance and beneficial microbes. The GFI value for site B is considered good/high compared to that of site A which is considered moderate/good. The SHI for site B is considered good and the SHI for site A is considered moderate.

Site B had higher levels of reactive carbon than site A (548.4 ppm vs. 468.6 ppm).

Reactive Carbon is more complex than the Labile Carbon in that its composed of all the dead and actively decomposing organic matter plus all the living soil microbial community that will eventually die and begin decomposing. Reactive carbon is linked to a number of soil processes, including microbial biomass growth and activity and nutrient cycling. Reactive carbon changes in soils can happen very quickly and a significant decrease in reactive carbon may signal a decline in soil organic matter and indicate the deterioration of physical, chemical, and biological properties and processes related to soil organic matter. The adverse effects caused by the decline in reactive carbon include reduced aggregate stability, increased bulk density, and reduced water infiltration, water-holding capacity, microbial activity, and nutrient availability. Reactive Carbon ranges based on the Cornell Assessment of Soil Health in ppm of Active Carbon for a medium Textured soil are Very Low 0-400, Low 400-500, Medium 500-600, High 600-700 and Very High >700. According to this scale Site A had low levels of reactive carbon while Site B had moderate levels of it.

The differences observed in the soil chemistry and microbial communities present at each site support the yield result differences at the two locations.

Table 3. Soil Analysis of Field 2.

Parameters	2A	2B
Yield (bu/ac)	203.1	311.3
Organic Matter (OM, %)	1.72	2.18
Phopsphorus (Bicarb, ppm)	45.4	92.2
Phopsphorus (Bray, ppm)	99.8	278
Potassium (K, ppm)	87.8	120.4
Magnesium (Mg, ppm)	103.4	135.4
Calcium (Ca, ppm)	1858	784
Sodium (Na, ppm)	8	10
Sulfur (S, ppm)	7.4	8.6
Zinc (Zn, ppm)	9.6	11.2
Manganese (Mn, ppm)	99.6	76.6
Iron (Fe, ppm)	67.2	109.8
Copper (Cu, ppm)	3.04	5.38
Boron (B, ppm)	0.36	0.14
Aluminum (Al, ppm)	402.6	742.4
CEC (meq/ 100g)	10.38	6.6
K/Mg Ratio	0.69	0.274
General Fertility Index (GFI)	65	81
Percent Base Saturation %K	2.16	4.68
%Mg	8.3	17.12
%Ca	89.28	59.48
%H	0	18.02
%Na	0.34	0.66
pH	7.74	6.1
Buffer pH		6.9
EC (ms/cm)	0.174	0.184
Saturation %P	6.8	48
Saturation %Al	0	0.88
Nitrate-N (ppm)	2	7.4
Chloride (ppm)	12	20.8
Potential Mineralizable Nitrogen (PMN, ppm)	33	38
Solvita CO2-C (ppm)	52.8	67
Reactive C (ppm)	468.6	548.4
Soil Health Index	34.2	42.6
%Microbial Active Carbon (MAC)	82.2	167.26
NRCS Soil Health Calculations	5.86	7.08
Biological Soil Quality	3.8	4
Estimated Nitrogen Release (ENR, lb/ac/year)	66	76

NRCS soil health calculations based on the Haney test results.

Microbial communities

As shown in Figures 3 (A and B), the bacterial communities of the roots from site A were all grouped above the 0 lines whereas those from site B were grouped below. This indicates that the bacterial communities from site A and B were different, but the differences were not sufficient as to be highly statistically valid as indicated by the overlapping confidence circles (Figure 3B). Similar results were observed for the fungal communities of site A and B (Figure 4). The TRFLP results for field 2 indicated that there are clear differences in the both the bacterial and fungal communities between the 2 sites sampled within the field. This is likely impacted by the differences in pH at the two sites (A = 7.74 and B = 6.1). More alkaline soils are bacterial dominant whereas acidic soils are fungal dominant.

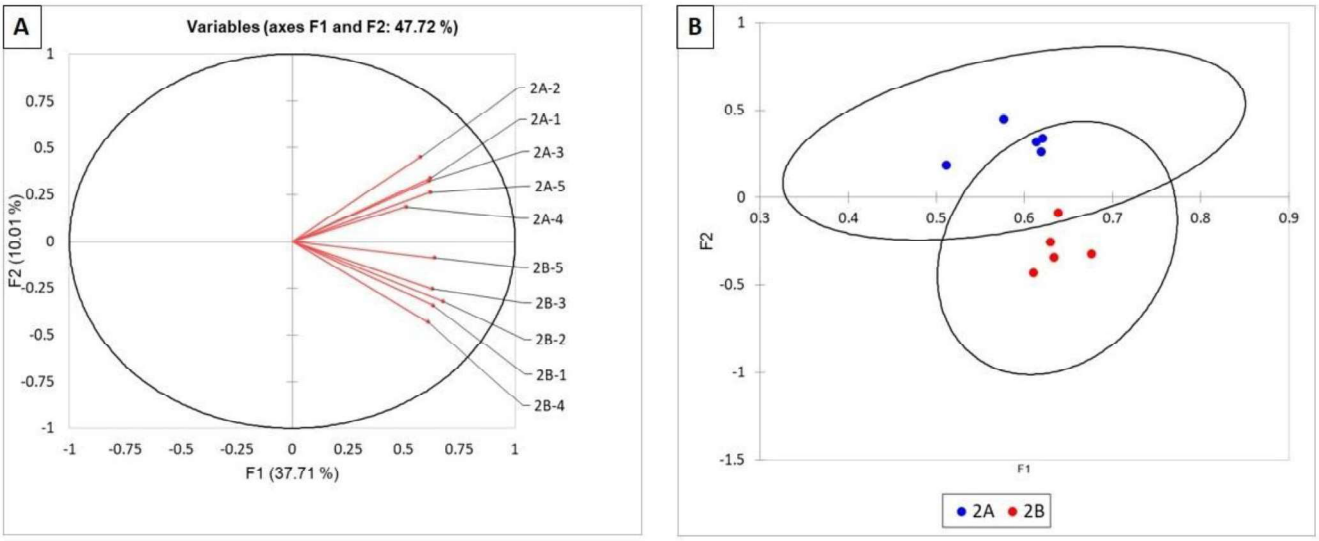

Figure 3. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 2. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

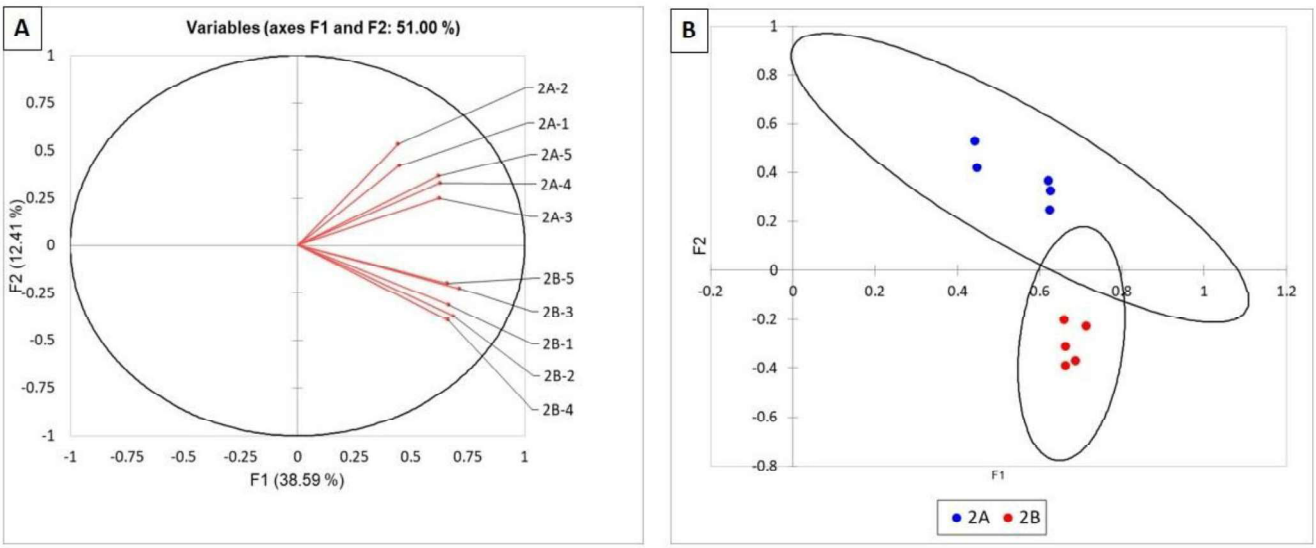

Figure 4. Statistical analysis of TRFLP of the fungal communities in corn roots of field 2. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 3

Site A produced 70.5 bu/ac more than site B (site A: 296 bu/ac vs. site B 225.5 bu/ac). A summary of the soil chemical analysis and yield of field 3 is presented in Table 4.

In this field site A had a higher organic matter content (5.36% vs. 4.6%), phosphorus (Bicarb 46.4 ppm vs. 22.2 ppm: Bray 107.2 ppm vs. 35.6 ppm), potassium (320.6 ppm vs. 114 ppm), and percent saturation potassium (3.82% vs. 2.38%) than site B. For this soil type, the percent saturation of potassium in site A and B both fall within the ideal range and the levels of phosphorus were considered good for site A and mediocre site B.

Site A had a higher GFI (74.4 vs. 59.8) and SHI (39 vs. 32.6) than site B. The GFI value for site A is considered good compared to that of site B which is considered moderate. The SHI values for site A and B are both considered moderate.

Site A had higher levels of reactive carbon than site B (1006 ppm vs. 788.4 ppm) although both sites were considered to have high levels of reactive carbon.

The differences observed in the soil chemistry and microbial communities present in each site support the yield results at the two locations

Table 4. Soil Analysis of Field 3.

Parameters	3A	3B
Yield (bu/ac)	296	225.5
Organic Matter (OM, %)	5.36	4.6
Phopsphorus (Bicarb, ppm)	46.4	22.2
Phopsphorus (Bray, ppm)	107.2	35.6
Potassium (K, ppm)	320.6	114
Magnesium (Mg, ppm)	252.8	349.4
Calcium (Ca, ppm)	3750	1524
Sodium (Na, ppm)	12	19.8
Sulfur (S, ppm)	9.6	10.2
Zinc (Zn, ppm)	6.52	3.32
Manganese (Mn, ppm)	19.2	12
Iron (Fe, ppm)	110.6	78.8
Copper (Cu, ppm)	2.2	1.02
Boron (B, ppm)	0.8	0.32
Aluminum (Al, ppm)	499.8	775.2
CEC (meq/ 100g)	21.72	12.32
K/Mg Ratio	0.392	0.102
General Fertility Index (GFI)	74.4	59.8
Percent Base Saturation %K	3.82	2.38
%Mg	9.72	23.7
%Ca	86.38	62.02
%H	0	11.2
%Na	0.22	0.7
pH	7.78	6.24
Buffer pH	0	6.88
EC (ms/cm)	0.31	0.198
Saturation %P	7.8	6
Saturation %Al	0	0.38
Nitrate-N (ppm)	10.2	3.8
Chloride (ppm)	11.4	16.6
Potential Mineralizable Nitrogen (PMN, ppm)	34.8	43.2
Solvita CO2-C (ppm)	57.2	84.4
Reactive C (ppm)	1006	788.4
Soil Health Index	39	32.6
%Microbial Active Carbon (MAC)	45.4	63.32
NRCS Soil Health Calculations	6.86	9.82
Biological Soil Quality	3.8	4.2
Estimated Nitrogen Release (ENR, lb/ac/year)	69.6	86.4

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities of roots from sites A and B in this field (Figures 5A and B).

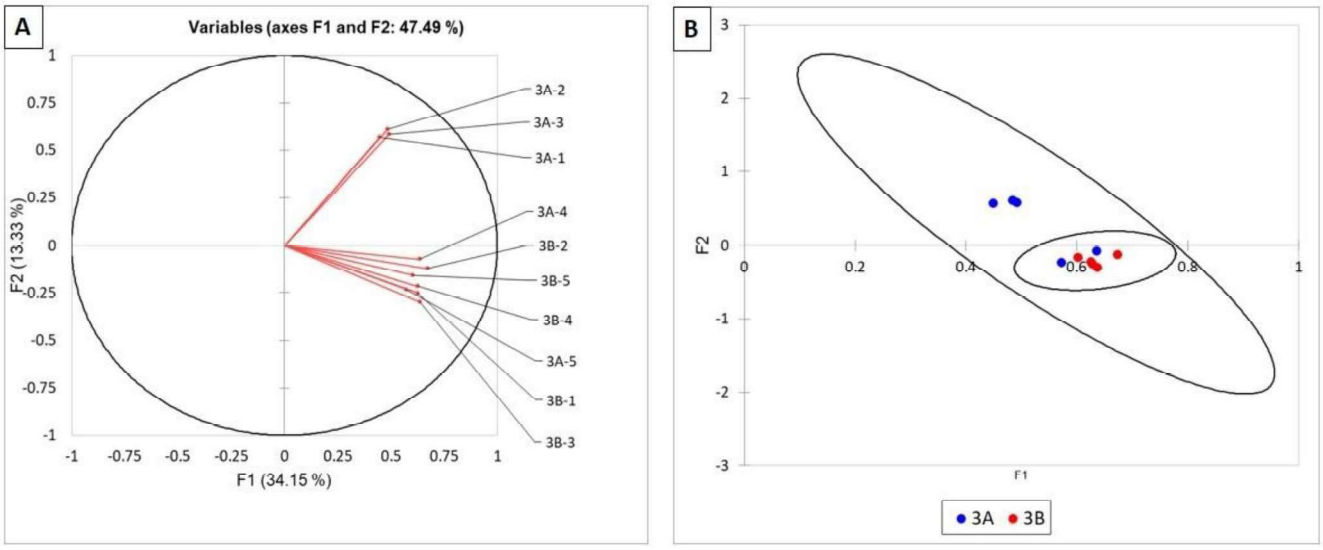

Figure 5. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 3. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

In contrast, the vectors of the fungal communities of the roots from site A were all grouped below the 0 line whereas those from site B were all above (figure 6A). The cluster analysis grouped all the A components close to each other and the B components samples were also closely related (Figure 6B, data as single points). This indicates that the fungal communities from site A and B were different, but the differences were not sufficient as to be highly statistically significant as indicated by the overlapping confidence circles, Figure 6B). At the same time this is indicative of that some clear differences in the fungal communities exist at the two locations again likely the result of pH effects.

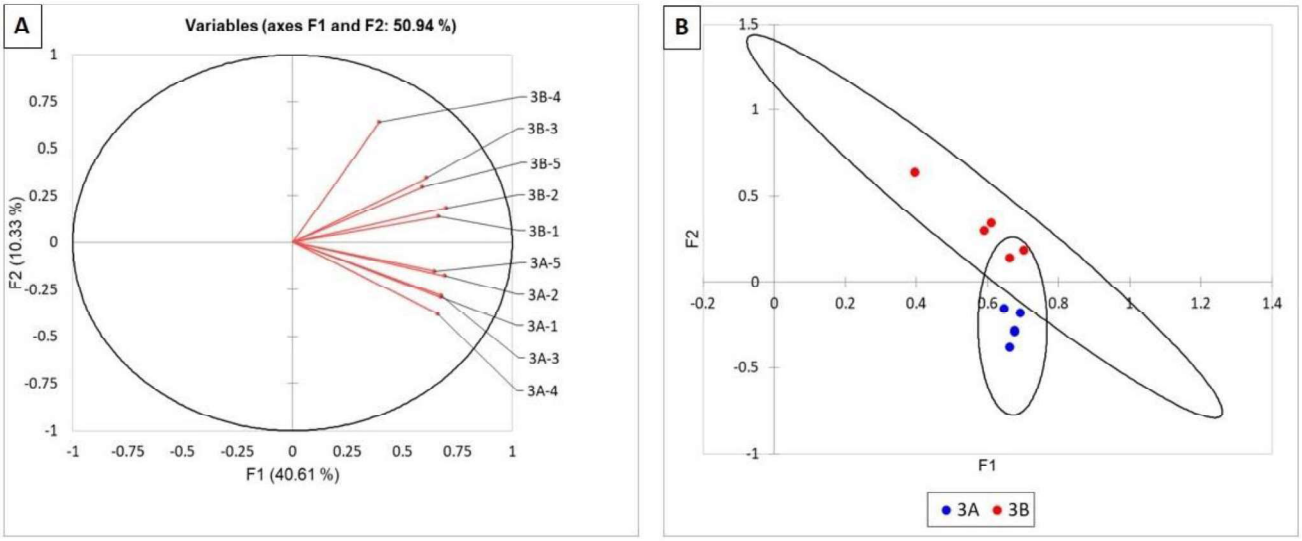

Figure 6. Statistical analysis of TRFLP of the fungal communities in corn roots of field 3. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Summary of Results (Table 5)

- Sites with different productivity level were successfully identified at all 3 fields studied (100% success, differences bigger than 5 bu/ac).
- Higher General Fertility index (GFI) and Soil Health Index (SHI) correlated with higher yields on 2 of the 3 fields.
- The Soil health Index predicted the 2 sites having the greatest yield differences (fields 2 and 3). Site 1 with lower yield differences (less than 20 bu/ac) had similar GFI and SHI values.
- Microbial population differences were reflected in soils with the greatest yield differences.

VitTellus is a Soil Health Test which assesses the chemical, physical and biological balance of the soil, and leads to agronomic strategies to improve soil health which drives greater nutrient utilization, higher crop yields and greater farm profitability.

This study provides clear evidence of the site variability in yields that if addressed could help growers produce better crops.

Table 5: Summary of Results

Site	Yield	Differences in bu/ac (field with higher yield)	GFI	SHI
1A	229.7	19.5 (B)	67.4	35.6
1B	249.2		64.4	36.2
2A	203.1	108.2 (B)	65	34.2
2B	311.3		81	42.6
3A	296	70.5 (A)	74.4	39
3B	225.5		59.8	32.6

Conclusions

The soil health test gives a complete overview of the chemical status of a soil and allows us to identify the differences between different production areas. It also provides growers with the optimal ranges of those chemical factor that highly correlate with yields and beneficial microbial activities.

Appendix 1

The tables presented below correspond to the summary of the results of the soil chemical analysis.

Field 1: Chemical Analysis

	Report # C20204-10015									
Parameters	1A-1	1A-2	1A-3	1A-4	1A-5	1B-1	1B-2	1B-3	1B-4	1B-5
Yield (bu/ac)	229.7	229.7	229.7	229.7	229.7	249.2	249.2	249.2	249.2	249.2
Organic Matter (OM, %)	3.5	3.2	3.6	3.7	3.7	4.1	4.1	4	4	4.1
Phopsphorus (Bicarb, ppm)	42	27	34	23	30	40	37	25	33	31
Phopsphorus (Bray, ppm)	73	49	55	46	49	68	64	50	57	56
Potassium (K, ppm)	152	135	162	150	156	130	142	122	132	149
Magnesium (Mg, ppm)	287	276	296	280	309	328	350	329	332	346
Calcium (Ca, ppm)	1870	1820	1940	1790	1930	2050	2130	2100	2080	2160
Sodium (Na, ppm)	14	15	14	13	14	16	15	15	15	15
Sulfur (S, ppm)	10	7	7	7	7	8	7	7	8	8
Zinc (Zn, ppm)	5.4	4.3	4.4	3.6	4	5.5	5	3.4	3.9	4.5
Manganese (Mn, ppm)	15	14	15	13	14	6	6	6	6	6
Iron (Fe, ppm)	75	73	78	69	73	81	80	78	83	84
Copper (Cu, ppm)	2.5	2.4	2.7	2.3	2.5	3.6	3.5	3.5	3.8	3.9
Boron (B, ppm)	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Aluminum (Al, ppm)	734	753	751	681	726	772	799	792	831	828
CEC (meq/ 100g)	13.4	13	13.8	12.9	13.9	14.6	15.2	14.8	14.7	15.3
K/Mg Ratio	0.16	0.15	0.17	0.17	0.16	0.12	0.13	0.11	0.12	0.12
General Fertility Index (GFI)	70	67	68	66	66	65	68	61	62	66
Percent Base Saturation %K	2.9	2.7	3	3	2.9	2.3	2.4	2.1	2.3	2.3
%Mg	17.9	17.7	17.9	18.1	18.6	18.8	19.2	18.5	18.8	18.9
%Ca	70	70.1	70.2	69.4	69.7	70.4	70.3	71	70.6	70.6
%H	8.7	9	8.5	9.1	8.4	8	7.7	7.9	7.9	7.6
%Na	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4
pH	6.7	6.6	6.7	6.9	6.8	6.9	6.8	6.8	6.8	6.8
Buffer pH	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
EC (ms/cm)	0.23	0.2	0.19	0.19	0.19	0.2	0.2	0.2	0.2	0.21
Saturation %P	13	8	9	9	9	11	10	8	9	9
Saturation %Al	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	7	5	4	5	4	4	4	5	3	4
Chloride (ppm)	9	9	13	9	9	8	9	9	8	9
Potential Mineralizable Nitrogen (PMN, ppm)	34	35	40	41	41	44	39	41	37	44
Solvita CO2-C (ppm)	55	56	72	75	77	86	68	77	63	86
Reactive C (ppm)	781	681	758	737	797	746	785	700	779	750
Soil Health Index	36	35	36	36	35	35	35	33	32	36
%Microbial Active Carbon (MAC)	49.3	47	60.5	47.4	65.4	62.3	63.8	69.7	40.8	65.9
NRCS Soil Health Calculations	6.5	6.8	8.3	9	8.8	9.9	7.8	8.8	7.8	9.8
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	68	70	80	82	82	88	78	82	74	88

Field 2: Chemical Analysis

	Report # C20204-10015									
Parameters	2A-1	2A-2	2A-3	2A-4	2A-5	2B-1	2B-2	2B-3	2B-4	2B-5
Yield (bu/ac)	203.1	203.1	203.1	203.1	203.1	311.3	311.3	311.3	311.3	311.3
Organic Matter (OM, %)	1.6	1.6	1.7	1.8	1.9	2.1	2.1	2.3	2.2	2.2
Phopsphorus (Bicarb, ppm)	50	40	44	48	45	97	87	87	93	97
Phopsphorus (Bray, ppm)	103	91	103	99	103	272	271	271	272	304
Potassium (K, ppm)	95	87	86	90	81	115	120	133	114	120
Magnesium (Mg, ppm)	102	105	105	105	100	126	129	133	142	147
Calcium (Ca, ppm)	1840	2100	1880	1740	1730	750	750	770	810	840
Sodium (Na, ppm)	7	9	9	7	8	10	10	9	11	10
Sulfur (S, ppm)	8	7	7	8	7	9	8	8	9	9
Zinc (Zn, ppm)	13.9	8	8.4	8.3	9.4	11.5	10.9	11.4	11.4	10.8
Manganese (Mn, ppm)	96	104	102	99	97	76	74	75	79	79
Iron (Fe, ppm)	65	69	69	67	66	108	109	109	109	114
Copper (Cu, ppm)	3.2	2.7	3.1	3	3.2	5.2	5.4	5.4	5.2	5.7
Boron (B, ppm)	0.3	0.3	0.4	0.4	0.4	0.1	0.2	0.2	0.1	0.1
Aluminum (Al, ppm)	403	404	418	428	360	718	747	708	746	793
CEC (meq/ 100g)	10.3	11.6	10.5	9.8	9.7	6.3	6.4	6.5	6.8	7
K/Mg Ratio	0.29	0.25	0.25	0.26	2.4	0.28	0.28	0.31	0.25	0.25
General Fertility Index (GFI)	66	64	65	66	64	83	84	81	79	78
Percent Base Saturation %K	2.4	1.9	2.1	2.3	2.1	4.7	4.8	5.2	4.3	4.4
%Mg	8.2	7.5	8.3	8.9	8.6	16.6	16.9	17	17.5	17.6
%Ca	89.2	90.3	89.3	88.6	89	59.3	58.9	59	59.9	60.3
%H	0	0	0	0	0	18.8	18.6	18.2	17.5	17
%Na	0.3	0.3	0.4	0.3	0.4	0.7	0.7	0.6	0.7	0.6
pH	7.8	7.8	7.7	7.7	7.7	6.1	6	6.1	6.1	6.2
Buffer pH	0	0	0	0	0	6.9	6.9	6.9	6.9	6.9
EC (ms/cm)	0.18	0.17	0.17	0.18	0.17	0.18	0.17	0.18	0.21	0.18
Saturation %P	7	6	7	7	7	49	46	49	47	49
Saturation %Al	0	0	0	0	0	0.9	1	0.8	0.8	0.9
Nitrate-N (ppm)	2	1	2	3	2	6	6	7	9	9
Chloride (ppm)	15	7	8	8	22	23	11	11	49	10
Potential Mineralizable Nitrogen (PMN, ppm)	36	29	33	33	34	41	41	35	41	32
Solvita CO2-C (ppm)	60	43	53	53	55	75	77	56	77	50
Reactive C (ppm)	480	423	476	442	522	503	552	591	578	518
Soil Health Index	35	33	34	35	34	44	45	42	42	40
%Microbial Active Carbon (MAC)	100.7	55.3	80.7	93.5	80.8	178.1	175.5	160.8	196.9	125
NRCS Soil Health Calculations	6.6	5	5.8	5.8	6.1	7.9	8.1	6	8.1	5.3
Biological Soil Quality	4	3	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	72	58	66	66	68	82	82	70	82	64

Field 3: Chemical Analysis

	Report # C20204-10015									
Parameters	3A-1	3A-2	3A-3	3A-4	3A-5	3B-1	3B-2	3B-3	3B-4	3B-5
Yield (bu/ac)										
Organic Matter (OM, %)	5.3	5.6	5.2	5.1	5.6	4.5	4.6	4.5	4.7	4.7
Phopsphorus (Bicarb, ppm)	47	48	44	43	50	21	21	23	19	27
Phopsphorus (Bray, ppm)	113	127	93	92	111	31	32	33	40	42
Potassium (K, ppm)	319	328	315	315	326	116	113	106	115	120
Magnesium (Mg, ppm)	243	259	250	254	258	339	355	334	346	373
Calcium (Ca, ppm)	3720	3860	3570	4090	3510	1540	1500	1530	1480	1570
Sodium (Na, ppm)	12	12	12	13	11	19	19	20	20	21
Sulfur (S, ppm)	9	10	10	10	9	10	10	10	11	10
Zinc (Zn, ppm)	6.1	7.1	6.2	7.1	6.1	3.2	3.2	3	3.9	3.3
Manganese (Mn, ppm)	20	19	19	21	17	10	12	10	13	15
Iron (Fe, ppm)	112	115	107	111	108	79	79	76	77	83
Copper (Cu, ppm)	2.3	2.4	2.2	2	2.1	1.1	1	0.9	1.1	1
Boron (B, ppm)	0.7	0.9	0.8	0.8	0.8	0.4	0.3	0.3	0.3	0.3
Aluminum (Al, ppm)	501	538	427	480	553	765	785	735	775	816
CEC (meq/ 100g)	21.5	22.3	20.8	23.4	20.6	12.1	12	12	11.8	13.7
K/Mg Ratio	0.4	0.39	0.39	0.39	0.39	0.11	0.1	0.1	0.1	0.1
General Fertility Index (GFI)	73	72	75	77	75	59	58	58	60	64
Percent Base Saturation %K	3.8	3.8	3.9	3.5	4.1	2.5	2.4	2.3	2.5	2.2
%Mg	9.4	9.7	10	9	10.5	23.4	24.7	23.3	24.4	22.7
%Ca	86.6	86.5	86	87.4	85.4	63.8	62.5	64	62.6	57.2
%H	0	0	0	0	0	9.6	9.7	9.7	9.8	17.2
%Na	0.2	0.2	0.3	0.2	0.2	0.7	0.7	0.7	0.7	0.7
pH	7.7	7.8	7.9	7.9	7.6	6.3	6.2	6.3	6.1	6.3
Buffer pH	0	0	0	0	0	6.9	6.9	6.9	6.9	6.8
EC (ms/cm)	0.32	0.31	0.31	0.31	0.3	0.19	0.2	0.2	0.21	0.19
Saturation %P	8	9	7	7	8	5	5	6	7	7
Saturation %Al	0	0	0	0	0	0.4	0.4	0.3	0.5	0.3
Nitrate-N (ppm)	12	10	10	9	10	3	4	4	5	3
Chloride (ppm)	12	12	10	12	11	14	16	17	17	19
Potential Mineralizable Nitrogen (PMN, ppm)	37	35	29	33	40	39	41	47	48	41
Solvita CO2-C (ppm)	63	56	42	53	72	68	75	98	104	77
Reactive C (ppm)	993	1027	972	1034	1004	808	792	805	744	793
Soil Health Index	39	38	38	40	40	31	31	33	34	34
%Microbial Active Carbon (MAC)	51.2	47.2	37.1	44.2	47.3	46.6	61	87.2	73.4	48.4
NRCS Soil Health Calculations	7.4	6.7	5.1	6.4	8.7	8.2	8.6	10.9	12.1	9.3
Biological Soil Quality	4	4	3	4	4	4	4	4	5	4
Estimated Nitrogen Release (ENR, lb/ac/year)	74	70	58	66	80	78	82	94	96	82

A&L Biologicals

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2019 - Soil Health Analysis of Corn Fields- Final report

Client name	Date
St.Clair Region Soil and Crop Improvement Association 2018-2020 Tier 2 Project	February 6, 2020

The **objective** of this work is to test A&L laboratories' VitTellus soil health analysis and how it corelates to yield and plant performance.

Methods

A&L received 180 corn roots with their respective root ball soil for analysis. The samples were collected by OMAFRA, Ridgetown office from eighteen corn field across South-Western Ontario. Before sample collection, NDVI maps of each field were created and used to select a healthy and a stressed area within each field. Using GPS guided sampling, 5 corn plants were collected per area for a total of 10 plants per field. The roots with their attached soil were code labelled, packaged individually and sent to A&L (Table 1).

Table 1. List of samples received for analysis

Field	Samples	Samples
1	1A-1 to 5	1B-1 to 5
2	2A-1 to 5	2B-1 to 5
3	3A-1 to 5	3B-1 to 5
5	5A-1 to 5	5B-1 to 5
6	6A-1 to 5	6B-1 to 5
7	7A-1 to 5	7B-1 to 5
8	8A-1 to 5	8B-1 to 5
9	9A-1 to 5	9B-1 to 5
10	10A-1 to 5	10B-1 to 5
11	11A-1 to 5	11B-1 to 5
12	12A-1 to 5	12B-1 to 5
13	13A-1 to 5	13B-1 to 5
14	14A-1 to 5	14B-1 to 5
15	15A-1 to 5	15B-1 to 5
16	16A-1 to 5	16B-1 to 5
17	17A-1 to 5	17B-1 to 5
19	19A-1 to 5	19B-1 to 5
20	20A-1 to 5	20B-1 to 5

Upon receiving the samples, the soil was separated from the roots and sent for the VitTellus soil health analysis. A total of 180 soil samples were analysed. The roots from 12 fields (fields 1, 2, 3, 5, 6, 8, 10, 11, 14, 16, 19, and 20) were washed with tap water, chopped into small pieces, and their DNA was extracted. The DNA was used to compare the root' microbial communities of plants from the two areas within each field.

Soil Health Analysis: VitTellus soil health test was used to determine the different chemical parameters of the soil, resulting in a Soil Health Index (SHI). This index ranges from 0 to 60, and the health of the soil is ranked as follow:

- SHI 0 – 20: very low soil health,
- SHI 20 – 30: low soil health,
- SHI 30 – 40: mediocre soil health,
- SHI 40 – 50: good soil health, and
- SHI 50 – 60: very good soil health

The VitTellus soil health test also provides growers with the optimal range for crop productivity of those chemical factors that our research has shown are directly correlated with yield and those microbial activities favourable to plant heath.

Analysis of the microbial communities: The root's microbial populations were analysed by Terminal Restriction Fragment Length Polymorphism (TRFLP). TRFLP is a fingerprinting technique for monitoring composition of microbial communities and it can be used to track spatial and temporal shifts in microbial populations. Briefly, a conserved region of DNA extracted from roots (16S rRNA gene for bacteria and ITS gene for fungi) were amplified with fluorescently labeled primers. The fluorescent PCR products were then digested with a restriction enzyme. The size and quantity of the fragments were determined using capillary electrophoresis. The banding pattern obtained provided a fingerprint of the microbial community. The relationship of such fingerprints to one another was identified using a multivariate statistical technique called Principle Component Analysis (PCA). Principle Components (PC) are statistical values generated to best explain the variation in a set of samples. TRFLP data was transformed into binary data (is a specific peak present (1) or not (0)) before performing PCA. PCA analysis clustered the data based on similarity of peak presence; 95% confidence intervals were automatically drawn around each sample group. Groups that do not overlap are consider statistically different in their microbial community.

Yield: Yields were determined by OMAFRA, Ridgetown by hand harvesting the same areas from where the mid season samples were collected. Final yields were kindly provided to us by Anne Verhallen, Soil Management Specialist (Horticultural Crops), Ontario Ministry of Agriculture, Food and Rural Affairs, Ridgetown, Ontario.

Results

Field 1

A summary of the soil chemical analysis and yield of field 1 is presented in Table 2. The numbers represent the average per area (A or B). Full chemical analysis per sample can be found in the appendix. Occasionally we encountered results that exceeded typical values found within a replicate analysis of a specific group of samples. In such cases the outlier values were discarded. The averages of the results with the outliers however, are presented in the appendix.

As shown on Table 2, the soil collected from site B had more organic matter (4.1% vs 3.3%), higher levels of phosphorus (215.2 ppm vs 147.6 ppm), percentage saturation of phosphorus (30.6% vs 26.6%), potassium and percentage saturation of potassium (183 ppm vs 131.8 ppm and 3.8% vs 2.7%, respectively) than site A. For this type of soil, a % saturation of potassium of 2.7% (site A) is considered low, while a 3.8% saturation K (site B) is within the optimal range for crop productivity. Soil from site B also had a better K/Mg ratio than site A (0.22 vs 0.17). Our research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. Similarly, site B had higher microbial respiration (Solvita 63.2 vs 57) and 70 ppm more Reactive Carbon than site A (Site B: 828.2 ppm vs site A: 758.2 ppm).

Reactive Carbon is more complex than the Labile Carbon in that its composed of all the dead and actively decomposing organic matter plus all the living soil microbial community that will eventually die and begin decomposing. Reactive carbon is linked to a number of soil processes, including microbial biomass growth and activity and nutrient cycling. Reactive carbon changes in soils can happen very quickly and a significant decrease in reactive carbon may signal a decline in soil organic matter and indicate the deterioration of physical, chemical, and biological properties and processes related to soil organic matter. The adverse effects caused by the decline in reactive carbon include reduced aggregate stability, increased bulk density, and reduced water infiltration, water-holding capacity, microbial activity, and nutrient availability. Reactive Carbon ranges based on the Cornell Assessment of Soil Health in ppm of Active Carbon for a medium Textured soil are Very Low 0-400, Low 400-500, Medium 500-600, High 600-700 and Very High >700.

Site B also had higher General fertility index (GFI 75 vs 68) and better Soil Health Index than the soils collected from site A (40 vs 36). A Soil Health Index (SHI) of 40 is considered good, while a SHI of 36 represents mediocre soil health. The pH on site B was slightly more acidic than the pH of site A (pH 6.2 vs 7.1).

Site B produced 95 bu/ac more than site A (1B: 194.6 bu/ac vs 1A: 99.3 bu/ac). The results for this site validate the projections of the VitTellus soil health test.

Table 2. Soil Analysis of Field 1.

	Report # C19231-10101	
Parameters	**1A**	**1B**
Yield (bu/ac)	99.3	194.6
Organic Matter (OM, %)	3.3	4.1
Phosphorus (Bicarb, ppm)	56.8	75.8
Phosphorus (Bray, ppm)	147.6	215.2
Potassium (K, ppm)	131.8	183.0
Magnesium (Mg, ppm)	247.0	253.4
Calcium (Ca, ppm)	1800.0	1672.0
Sodium (Na, ppm)	15.0	12.4
Sulfur (S, ppm)	11.6	10.8
Zinc (Zn, ppm)	4.3	6.0
Manganese (Mn, ppm)	25.2	7.8
Iron (Fe, ppm)	81.8	117.4
Copper (Cu, ppm)	1.2	2.3
Boron (B, ppm)	0.4	0.4
Aluminum (Al, ppm)	703.0	898.2
CEC (meq/ 100g)	12.6	12.4
K/Mg Ratio	0.17	0.22
General Fertility Index (GFI)	68	75
Percent Base Saturation %K	2.7	3.8
%Mg	16.4	17.0
%Ca	71.3	67.4
%H	9.1	11.3
%Na	0.5	0.4
pH	7.1	6.2
Buffer pH	6.9	6.9
EC (ms/cm)	0.2	0.2
Saturation %P	26.6	30.6
Saturation %Al	0.1	0.48
Nitrate-N (ppm)	1	2.8
Chloride (ppm)	44.8	34.4
Potential Mineralizable Nitrogen (PMN, ppm)	34.6	37.0
Water Extracted Organic C (ppm)	128.4	109.2
Water Extracted Inorganic N (ppm)	2.7	2.6
Water Extracted Organic N (ppm)	15.3	17.4
Solvita CO2-C (ppm)	57.0	63.2
Reactive C (ppm)	758.2	828.2
Soil Health Index	36	40
%Microbial Active Carbon (MAC)	43.7	58.1
Organic C:N ratio	8.9	8.9
NRCS Soil Health Calculations	8.5	8.5
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	44.8	52.8
Water extracted total N	18.0	20.0
Water extracted Soil Nitrate	1.6	1.2
Water extracted Soil Ammonium	1.4	1.8

NRCS soil health calculations based on the Haney test results.

Microbial communities

The composition of the bacterial and fungal communities of roots from sites A and B were analysed using TRFLP. We compared the microbial communities from both sites and summarized the results in two different ways: **(A) As vectors:** Figures 1A and 2A show each TRFLP result as a vector (bacterial and fungal, respectively). Each vector represents the community of one plant (named 1- 5). The closer the vectors are to each other, the more similar are the populations they represent. **(B) As single data point:** To visualize if there were any statistically significant differences between the communities from site A and B, we summarized our results as single data points and plotted them two dimensionally (Figures 1B and 2B). The degree of separation between dots indicates the extent of similarities or differences. The further the dots are separated, the greater the difference. The closer they are, the more similar the population. Confidence circles (95%) that do not overlap are considered significantly different.

As shown on Figure 1A, the bacterial communities of the roots from site A clustered together on the bottom right quadrant of the graph, suggesting they were similar among samples. In contrast, only 3 of the 5 samples from site B clustered together (on the top right quadrant of the graph), the other two (1B-1 and 1B-2) clustered with the samples from site A, indicating they were more similar to those samples than to the samples from site B. Statistical analysis of these results (Figure 1B, data as single points) showed that although the bacterial communities from site A and B where somehow different, the differences were not statistically significant (overlapping confidence circles, Figure 1B).

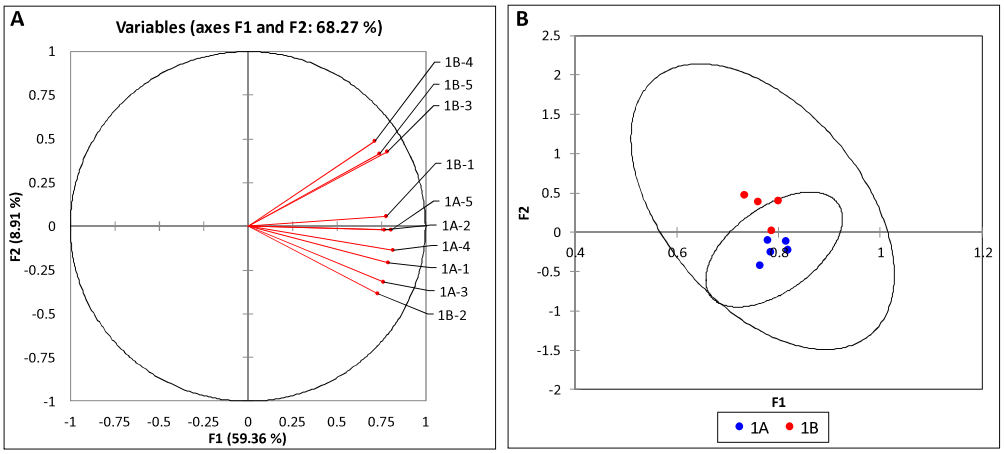

Figure 1. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 1. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

No differences in the fungal communities of roots from site A and B were found (Figure 2A and B). All samples clustered together indicating that their fungal communities were similar.

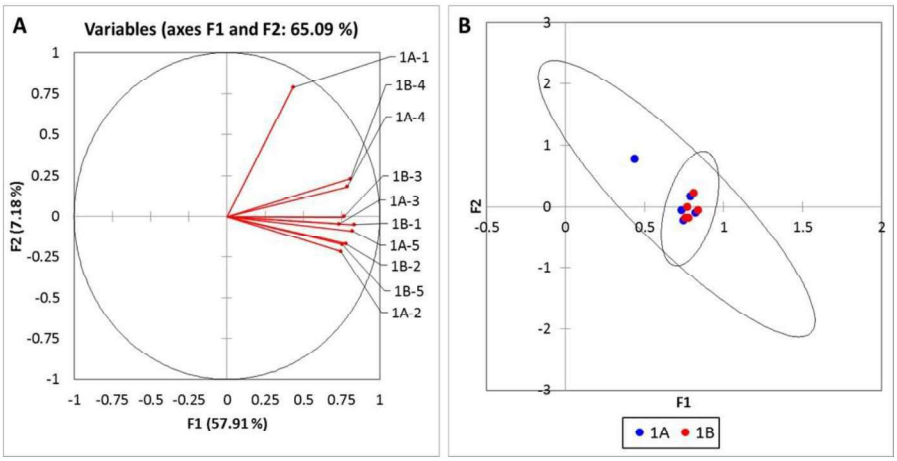

Figure 2. Statistical analysis of TRFLP of the fungal communities in corn roots of field 1. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 2

A summary of the soil chemical analysis and yield of field 2 is presented in Table 3.

In this field, soil from site A had higher levels of phosphorus (58.2 ppm vs 35.2 ppm) and percentage saturation of phosphorus than site B (4.8% vs 2.8%). For this type of soil, a % saturation of phosphorus of 4.8% (site A) is considered low, while a 2.8% saturation phosphorus (site B) is consider very low. In contrast, site B had almost double the amount of potassium (110.2 ppm vs 63.8 ppm) and percentage saturation of potassium than site A (2.1% vs 1.3%). Our previous research has shown that the % saturation of potassium is one of the top 5 factors that correlate with crop yield. In this case, both sites are below the optimum range of potassium saturation (3% - 5%).

Site B also had more manganese than site A (67.6 ppm vs 38.2 ppm). Both sites had poor K/Mg ratios (0.11 vs 0.15), as a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity.

Although site A had higher General Fertility Index than site B (GFI 64 vs 57), both GFI are considered as medium. Both sites had low soil respiration (42.8 and 42.6) and similar biological soil quality (3 vs 3.6). Site A had 91.6 ppm more of Reactive Carbon (824.2 ppm vs 732.6 ppm), and a slightly higher Soil Health Index than site B (33 vs 30), however, both SHI are considered to represents soils with mediocre soil health.

Site B produced 26.5 bu/ac more than site A (2B: 243.9 bu/ac vs 2A: 217.4 bu/ac). While the soil health indexes do not differentiate the two soils the differences in K levels and the better K/Mg ratios would predict that site B would be more productive.

Table 3. Soil Analysis of Field 2.

	Report # C19225-10012	
Parameters	**2A**	**2B**
Yield (bu/ac)	217.4	243.9
Organic Matter (OM, %)	3.9	3.4
Phosphorus (Bicarb, ppm)	32.4	22.4
Phosphorus (Bray, ppm)	58.2	35.2
Potassium (K, ppm)	63.8	110.2
Magnesium (Mg, ppm)	181.8	220.4
Calcium (Ca, ppm)	2016.0	2196.0
Sodium (Na, ppm)	9.8	8.6
Sulfur (S, ppm)	9.2	8.4
Zinc (Zn, ppm)	12.6	9.8
Manganese (Mn, ppm)	38.2	67.6
Iron (Fe, ppm)	68.0	51.2
Copper (Cu, ppm)	3.5	4.1
Boron (B, ppm)	0.4	0.7
Aluminum (Al, ppm)	552.0	575.0
CEC (meq/ 100g)	13.0	13.2
K/Mg Ratio	0.11	0.15
General Fertility Index (GFI)	64	57
Percent Base Saturation %K	1.3	2.1
%Mg	11.7	13.9
%Ca	77.6	82.9
%H	9.1	0.9
%Na	0.3	0.3
pH	6.7	7.3
Buffer pH	6.9	
EC (ms/cm)	0.2	0.2
Saturation %P	4.8	2.8
Saturation %Al	0.12	0.04
Nitrate-N (ppm)	9.4	7.2
Chloride (ppm)	13.4	10.6
Potential Mineralizable Nitrogen (PMN, ppm)	29.4	29.4
Water Extracted Organic C (ppm)	211.6	202.5
Water Extracted Inorganic N (ppm)	9.1	11.3
Water Extracted Organic N (ppm)	24.9	32.7
Solvita CO2-C (ppm)	42.8	42.6
Reactive C (ppm)	824.2	732.6
Soil Health Index	33	30
%Microbial Active Carbon (MAC)	23.78	22.55
Organic C:N ratio	9.02	6.175
NRCS Soil Health Calculations	8.22	8.775
Biological Soil Quality	3	3.6
Estimated Nitrogen Release (ENR, lb/ac/year)	51.2	45.6
Water extracted total N	34	44
Water extracted Soil Nitrate	7.6	8.8
Water extracted Soil Ammonium	1.4	2.8

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities (Figure 3) nor on the fungal communities (Figure 4) of roots from sites A and B in this field. Our previous research had shown that when the Soil Health Indexes are similar, in this case 33 and 30, and the difference in production is less than 30 bu/ac, no differences in the plant's microbiome can be detected with this technology.

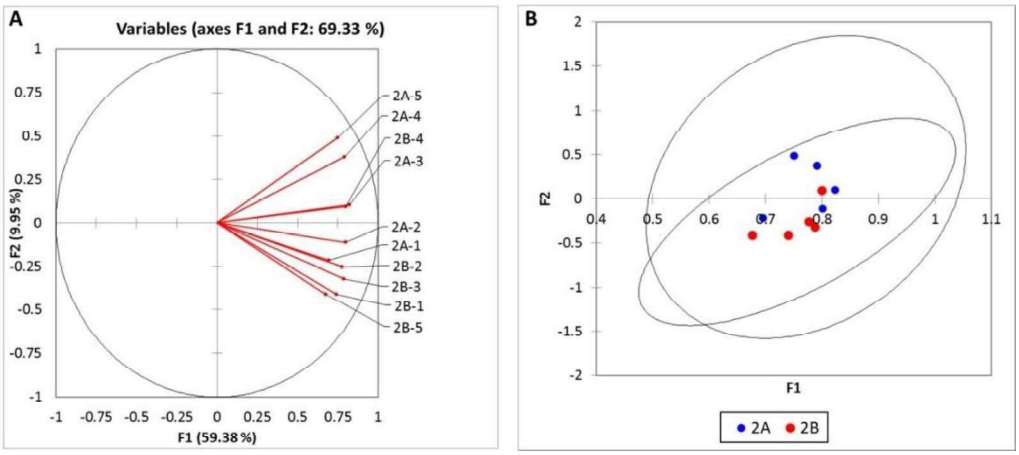

Figure 3. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 2. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

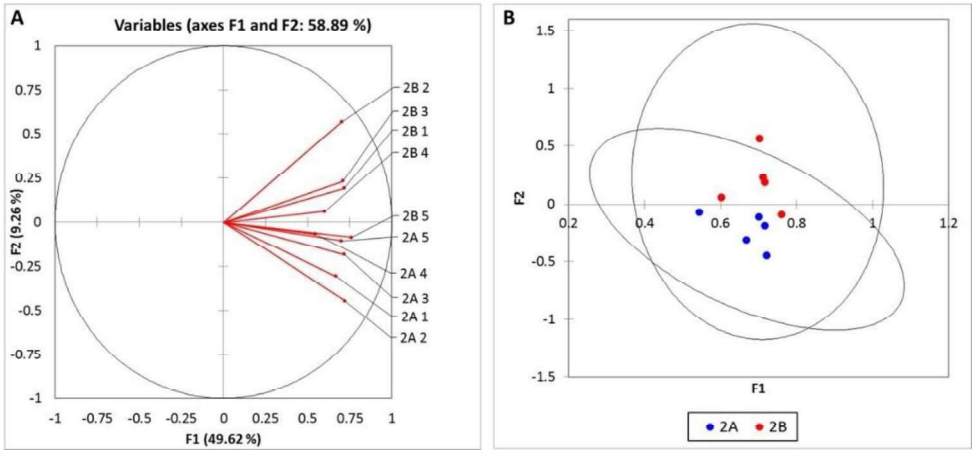

Figure 4. Statistical analysis of TRFLP of the fungal communities in corn roots of field 2. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 3

A summary of the soil chemical analysis and yield of field 3 is presented in Table 4.

Soil from site A had higher level of phosphorus (56.8 ppm vs 42.8 ppm) and percentage saturation of phosphorus (10.8% vs 6.4 %) than site B. On this type of soil, a 10% phosphorus saturation is considered good while a 6% is consider medium. Site A also had higher percentage saturation of magnesium (16.6% vs 13.9 %), and higher levels of manganese than site B (12.6 ppm vs 4.6 ppm).

Site A had higher microbial respiration rate than site B (57.8 vs 45.5); both rates are considered low to medium soil respiration. Site A also had higher biological soil quality (4 vs 3.5), and Reactive Carbon levels than site B (790.3 ppm vs 737.3 ppm). Both sites had low K/Mg ratio (0.11 vs 0.18), and similar general fertility index (GFI 64 vs 66) and a mediocre Soil Health Index (34 vs 35). Both sites had adequate K levels.

Site A produced 23.8 bu/ ac more than site B (3A: 175.4 bu/ac vs 3B: 151.6 bu/ac). The results while similar do not align with the predicted yields of the VitTellus model.

Table 4. Soil Analysis of Field 3.

	Report # C19231-10101	
Parameters	**3A**	**3B**
Yield (bu/ac)	175.4	151.6
Organic Matter (OM, %)	3.5	3.7
Phosphorus (Bicarb, ppm)	30.6	23.8
Phosphorus (Bray, ppm)	56.8	42.8
Potassium (K, ppm)	102.2	139.4
Magnesium (Mg, ppm)	274.6	240.2
Calcium (Ca, ppm)	1588.0	2040.0
Sodium (Na, ppm)	11.6	12.6
Sulfur (S, ppm)	7.4	8.4
Zinc (Zn, ppm)	3.1	3.2
Manganese (Mn, ppm)	12.6	4.6
Iron (Fe, ppm)	73.2	99.0
Copper (Cu, ppm)	1.7	2.2
Boron (B, ppm)	0.4	0.4
Aluminum (Al, ppm)	663.6	878.8
CEC (meq/ 100g)	11.7	14.5
K/Mg Ratio	0.11	0.18
General Fertility Index (GFI)	64	66
Percent Base Saturation %K	2.2	2.5
%Mg	19.6	13.9
%Ca	67.8	70.9
%H	10.0	12.4
%Na	0.4	0.4
pH	6.5	6.3
Buffer pH	6.9	6.8
EC (ms/cm)	0.1	0.2
Saturation %P	10.8	6.4
Saturation %Al	0.24	0.36
Nitrate-N (ppm)	1.8	3
Chloride (ppm)	21.0	19.4
Potential Mineralizable Nitrogen (PMN, ppm)	35.0	30.5
Water Extracted Organic C (ppm)	97.5	160.5
Water Extracted Inorganic N (ppm)	2.5	5.3
Water Extracted Organic N (ppm)	20.0	32.3
Solvita CO2-C (ppm)	57.8	45.5
Reactive C (ppm)	790.3	737.3
Soil Health Index	34	35
%Microbial Active Carbon (MAC)	59.7	28.7
Organic C:N ratio	8	5.5
NRCS Soil Health Calculations	7.65	7.68
Biological Soil Quality	4	3.5
Estimated Nitrogen Release (ENR, lb/ac/year)	46.6	48.6
Water extracted total N	22.5	37.5
Water extracted Soil Nitrate	1	2.75
Water extracted Soil Ammonium	1.75	2.5

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site A were similar to each other, as evident from the clustering of the samples on the top right quadrant of the graph (Figure 5 A). The root's bacterial populations from site B were also similar to each other, as indicated by the clustering of the samples on the bottom right quadrant of the graph (Figure 5A). Although the bacterial communities from sites A and B were somehow different (grouped in clusters), the differences were not statistically significant (Figure 5B).

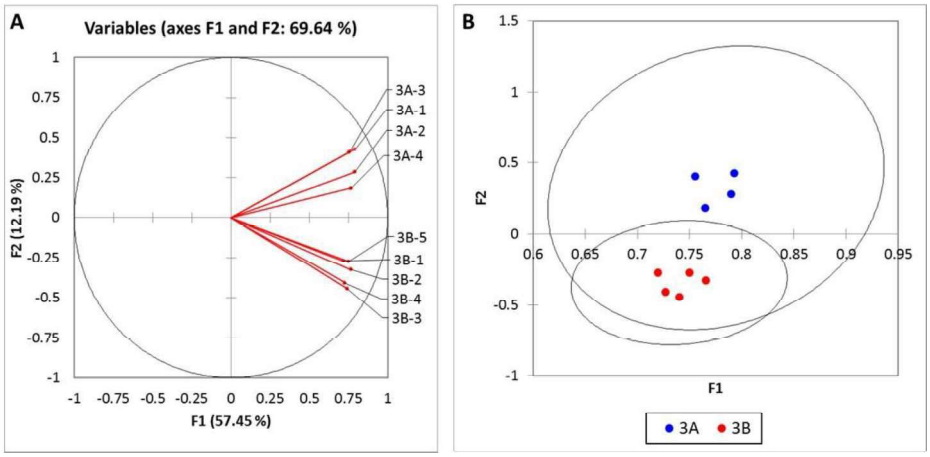

Figure 5. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 3. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

A similar pattern was observed in the case of the fungal communities. Although the fungal populations of roots from sites A and B were somehow different (Figure 6), they cannot be separated in two distinct groups (Figure 6B).

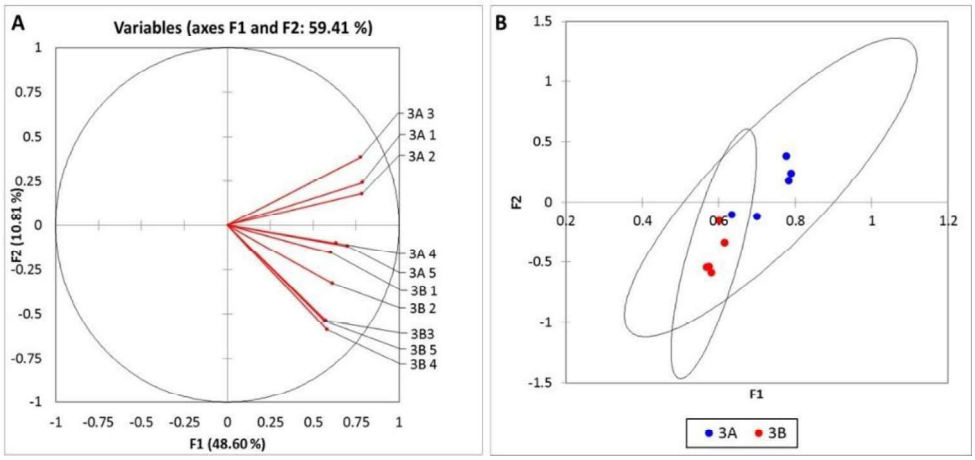

Figure 6. Statistical analysis of TRFLP of the fungal communities in corn roots of field 3. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 5

A summary of the soil chemical analysis and yield of field 5 is presented in Table 5.

Soil collected from site A had more phosphorus (65.6 ppm vs 42.4 ppm) and higher percentage saturation of phosphorus (10% vs 6.4%) than site B. In this soil, 10% phosphorus saturation is considered high while a 6% saturation is considered medium. Site A also had higher levels of potassium (149.6 ppm vs 123.4 ppm), magnesium (250 ppm vs 219 ppm), and double the amount of boron (0.4 ppm vs 0.2 ppm) than the soil from site B. Both sites had low K/Mg ratio (A: 0.19 and B: 0.17). A K/Mg ratio between 0.25 and 0.35 is optimal for crop productivity.

Soils from site A had a better General Fertility Index (GFI) and Soil Health Index (SHI) than the soils collected from site B (GFI 76 vs 68, SHI 41 vs 36). A SHI of 41 (Site A) represent good soil health, while a SHI of 36 (Site B) is considered mediocre.

The pH on both sets of soil was low (pH 5.7 and 5.6), reducing the yield potential of this field.

Site A produced 7.6 bu/ac more than site B (5A: 180.1 bu/ac vs 172.5 bu/ac). Although the yield differences were small the data does agree with VitTellus projection. Based on the relatively mediocre yields this field should have produced a much better result. Increasing soil pH may help to resolve this.

Table 5. Soil Analysis of Field 5.

	Report # C19231-10101	
Parameters	**5A**	**5B**
Yield (bu/ac)	180.1	172.5
Organic Matter (OM, %)	3.9	3.2
Phosphorus (Bicarb, ppm)	32.8	23.4
Phosphorus (Bray, ppm)	65.6	42.4
Potassium (K, ppm)	149.6	123.4
Magnesium (Mg, ppm)	250.0	219.0
Calcium (Ca, ppm)	1610.0	1382.0
Sodium (Na, ppm)	13.6	14.2
Sulfur (S, ppm)	9.8	8.8
Zinc (Zn, ppm)	5.1	3.7
Manganese (Mn, ppm)	5.4	5.6
Iron (Fe, ppm)	122.6	118.0
Copper (Cu, ppm)	3.0	1.7
Boron (B, ppm)	0.4	0.2
Aluminum (Al, ppm)	848.4	874.4
CEC (meq/ 100g)	14.7	13.4
K/Mg Ratio	0.19	0.17
General Fertility Index (GFI)	76	68
Percent Base Saturation %K	2.6	2.4
%Mg	14.3	13.8
%Ca	55.2	52.2
%H	27.5	31.1
%Na	0.4	0.5
pH	5.7	5.6
Buffer pH	6.7	6.6
EC (ms/cm)	0.2	0.2
Saturation %P	10	6.4
Saturation %Al	0.88	1.08
Nitrate-N (ppm)	1.4	1.4
Chloride (ppm)	16.2	14.8
Potential Mineralizable Nitrogen (PMN, ppm)	31.2	25.0
Water Extracted Organic C (ppm)	190.8	198.0
Water Extracted Inorganic N (ppm)	5.3	4.0
Water Extracted Organic N (ppm)	36.7	36.0
Solvita CO2-C (ppm)	47.4	38
Reactive C (ppm)	770.4	706.6
Soil Health Index	41	36
%Microbial Active Carbon (MAC)	25.36	17.52
Organic C:N ratio	5.78	5.58
NRCS Soil Health Calculations	7.94	8.32
Biological Soil Quality	4	2.8
Estimated Nitrogen Release (ENR, lb/ac/year)	51	43.6
Water extracted total N	42	40
Water extracted Soil Nitrate	1.8	1
Water extracted Soil Ammonium	4.2	3

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found on the bacterial populations of roots from site A and B (Figure 7B). In contrast, the fungal communities from sites A and B clearly separated (Figure 8A), highlighting the differences between them. However, those differences were not statistically significant as indicated by the touching confidence circles (Figure 8B).

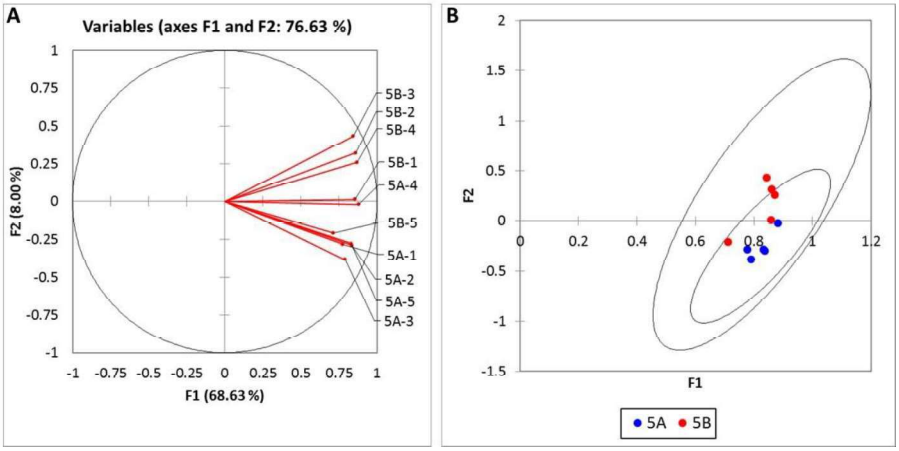

Figure 7. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 5. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

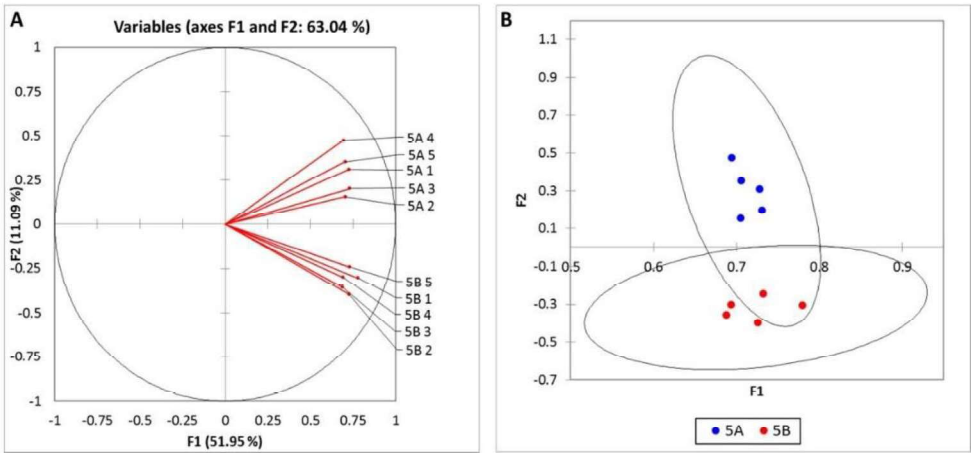

Figure 8. Statistical analysis of TRFLP of the fungal communities in corn roots of field 5. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 6

A summary of the soil chemical analysis and yield of field 6 is presented in Table 6.

The soil from site A had at least double the % saturation of potassium than the soil from site B (7.3% vs 3.1%). For these soils a 7.3% saturation of potassium is considered high, while a 3.1% saturation is considered optimal for crop productivity. Similarly, site A had a % saturation of phosphorus three times higher than site B (82.4% vs 27.2%). In this case both numbers are considered exceptionally high. Site B had two times more manganese (56.4 ppm vs 25.6 ppm), 1.8 times more boron (0.9 ppm vs 0.5 pm) and a better K/Mg ratio than site A (0.25 vs 0.57). A K/Mg of 0.25 is within the range considered ideal for crop productivity (0.25 – 0.35).

Site A had a low to medium soil respiration (40 ppm CO_2) while the soil respiration of site B was very low (27.6 ppm CO_2). Both sites had similar general fertility index (67 and 66), similar biological quality (3 vs 3.2), similar levels of Reactive Carbon (817.4 ppm vs 811.8 ppm) and the same Soil Health Index (36, Table 6). That SHI represent soils with mediocre soil health.

Site B produced 58.7 bu/ac more than site A (Site A: 187.8 vs Site B: 246.5). This soil has many unusual chemical characteristics that differentiate it from the other sites sampled. The yields obtained are difficult to explain based on the soil chemistry as they appear to be very unbalanced. A partial explanation lies in the much better K:Mg ratio of site B, which is always our top indicator of soil heath.

Table 6. Soil Analysis of Field 6.

	Report # C19218-10092	
Parameters	**6A**	**6B**
Yield (bu/ac)	187.8	246.5
Organic Matter (OM, %)	3.7	3.2
Phosphorus (Bicarb, ppm)	167.4	116.8
Phosphorus (Bray, ppm)	501.6	348.8
Potassium (K, ppm)	334.2	157.4
Magnesium (Mg, ppm)	181.0	191.0
Calcium (Ca, ppm)	1636.0	2172.0
Sodium (Na, ppm)	12.6	17.0
Sulfur (S, ppm)	12.8	15.6
Zinc (Zn, ppm)	25.8	22.3
Manganese (Mn, ppm)	25.6	56.4
Iron (Fe, ppm)	167.2	147.0
Copper (Cu, ppm)	3.5	5.4
Boron (B, ppm)	0.5	0.9
Aluminum (Al, ppm)	782.6	532.6
CEC (meq/ 100g)	11.8	13.2
K/Mg Ratio	0.57	0.25
General Fertility Index (GFI)	67	66
Percent Base Saturation %K	7.3	3.1
%Mg	12.8	12.1
%Ca	69.4	82.6
%H	10.0	1.8
%Na	0.5	0.6
pH	6.7	7.3
Buffer pH	6.9	
EC (ms/cm)	0.2	0.2
Saturation %P	82.4	27.2
Saturation %Al	0.18	0.06
Nitrate-N (ppm)	4.2	4
Chloride (ppm)	28.2	25.0
Potential Mineralizable Nitrogen (PMN, ppm)	28.0	22.0
Water Extracted Organic C (ppm)	214.0	171.6
Water Extracted Inorganic N (ppm)	30.0	24.4
Water Extracted Organic N (ppm)	16.0	21.6
Solvita CO2-C (ppm)	40.0	27.6
Reactive C (ppm)	817.4	811.8
Soil Health Index	36	36
%Microbial Active Carbon (MAC)	18.8	16.6
Organic C:N ratio	13.9	9.4
NRCS Soil Health Calculations	7.7	6.7
Biological Soil Quality	3	3.2
Estimated Nitrogen Release (ENR, lb/ac/year)	49.2	44
Water extracted total N	46	46
Water extracted Soil Nitrate	26.8	21.2
Water extracted Soil Ammonium	3.6	3.4

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from sites A and B tend to separate, indicating that they were somehow different (Figure 9). However, the differences were not statistically significant (Figure 9B). No differences were found in the fungal communities of roots from site A and B (Figure 10). Our previous results have shown that when the fertility of soils is very similar, independently of fertility level, no differences in the microbiology of plants growing in those soils can be identified using TRFLP analysis.

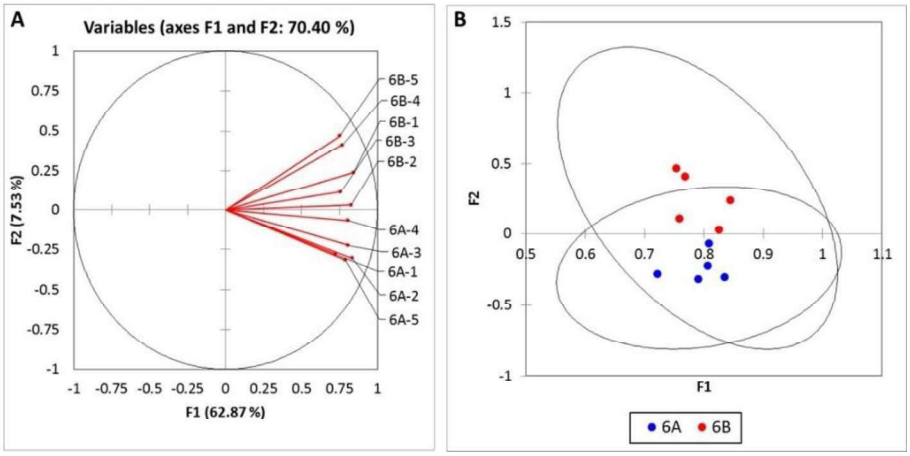

Figure 9. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 6. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

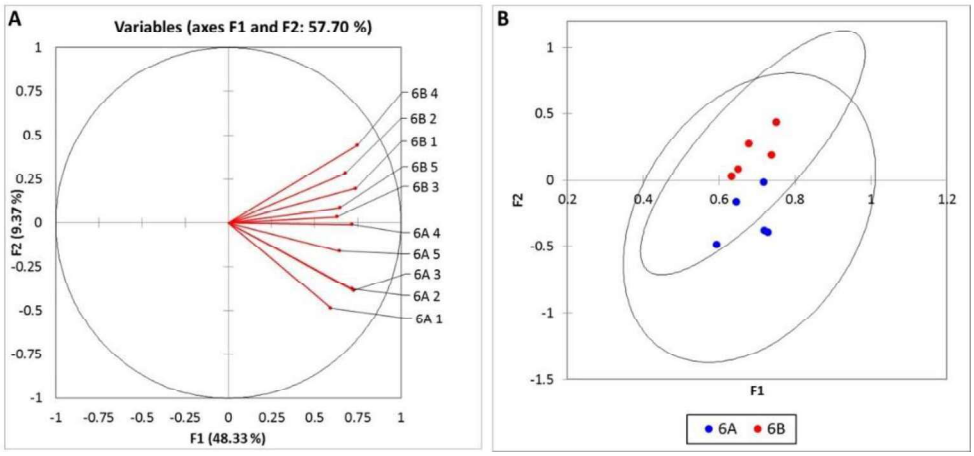

Figure 10. Statistical analysis of TRFLP of the fungal communities in corn roots of field 6. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 7

A summary of the soil chemical analysis and yield of field 7 is presented in Table 7.

In this field the soil from site A had higher levels of organic matter (2.5% vs 1.7%) and higher levels of calcium (2344 ppm vs 1644 ppm) than site B. The % saturation of calcium of both soils was ranked as high (87.3% and 80.5%). Similarly, both sites had high % saturation of phosphorus (10% and 12.4%). The % saturation of potassium and magnesium of site A were considered low, while on site B were considered optimal for crop productivity (%K: 2.5% vs 4.5%; %Mg: 9.9% vs 14.6%).

The soil respiration (Solvita) and the Soil Health index were very similar on both sites (Solvita 45 vs 45.8; SHI 38 vs 39). The SHI were considered mediocre. Site A had more reactive carbon than site B (660.2 ppm vs 493.6 ppm). Based on the Cornell assessment of soil health in ppm of active carbon for a medium textured soil (Very Low 0-400, Low 400-500, Medium 500-600, High 600-700 and Very High >700), site A had high levels of reactive carbon (660 ppm) while site B had low levels (493 ppm).

Site A produced 10.6 bu/ac more than site B (Site A: 216.6 bu/ac vs Site B: 206 bu/ac). This is well within the variance in sampling. The very decent yields here are supportive of the VitTellus and K:Mg ratio data.

Table 7. Soil Analysis of Field 7.

	Report # C19218-10093	
Parameters	**7A**	**7B**
Yield (bu/ac)	216.6	206
Organic Matter (OM, %)	2.5	1.7
Phosphorus (Bicarb, ppm)	56.2	56.6
Phosphorus (Bray, ppm)	137.6	156.2
Potassium (K, ppm)	132.8	181.6
Magnesium (Mg, ppm)	160.0	179.0
Calcium (Ca, ppm)	2344.0	1644.0
Sodium (Na, ppm)	12.6	12.2
Sulfur (S, ppm)	20.6	16.0
Zinc (Zn, ppm)	8.6	11.6
Manganese (Mn, ppm)	141.8	143.2
Iron (Fe, ppm)	90.2	88.6
Copper (Cu, ppm)	2.5	4.8
Boron (B, ppm)	0.9	0.9
Aluminum (Al, ppm)	615.2	630.8
CEC (meq/ 100g)	13.4	10.2
K/Mg Ratio	0.26	0.31
General Fertility Index (GFI)	69	72
Percent Base Saturation %K	2.5	4.5
%Mg	9.9	14.6
%Ca	87.3	80.5
%H	0.0	0.0
%Na	0.4	0.5
pH	7.5	7.5
Buffer pH		
EC (ms/cm)	0.3	0.2
Saturation %P	10	12.4
Saturation %Al	0	0.06
Nitrate-N (ppm)	2.2	2.6
Chloride (ppm)	11.8	48.8
Potential Mineralizable Nitrogen (PMN, ppm)	30.0	30.4
Water Extracted Organic C (ppm)	175.6	233.2
Water Extracted Inorganic N (ppm)	28.3	51.0
Water Extracted Organic N (ppm)	1.1	0.6
Solvita CO2-C (ppm)	45.0	45.8
Reactive C (ppm)	660.2	493.6
Soil Health Index	38	39
%Microbial Active Carbon (MAC)	25.9	20.1
Organic C:N ratio	245.3	419.3
NRCS Soil Health Calculations	6.32	6.96
Biological Soil Quality	3	3.6
Estimated Nitrogen Release (ENR, lb/ac/year)	37	29
Water extracted total N	29.4	51.6
Water extracted Soil Nitrate	24.2	45
Water extracted Soil Ammonium	4.2	6.2

NRCS soil health calculations based on the Haney test results.

Field 8

A summary of the soil chemical analysis and yield of field 8 is presented in Table 8.

Site B had almost double the amount of phosphorus (117 ppm vs 69.2 ppm) and more than double the % saturation of phosphorus than site A (17% vs 7.4%). A 17% phosphorus saturation is considered high while the % saturation of phosphorus of site A is considered medium. Similarly, site B had almost double the amount of potassium (112.4 ppm vs 59.8 ppm), and almost 4 times the amount of nitrate (34.6 ppm vs 9.2 ppm) than site A.

The GFI and SHI were also higher in site B than A (GFI 72 vs 61; SHI 38 vs 32). Even though the SHI of Site B was higher than the one of Site A, both SHI represents a mediocre soil health. Even though site B had a more balance soil chemistry and a better soil health index than site A, the pH of this site is only 5.5 vs a pH of 7 on site A. The low pH is affecting crop productivity. Liming the area of site B in this field will increase overall crop productivity. The very low K:Mg ratios are also indicating a need for adjusting soil chemistry.

Both sites had the same soil respiration (80.4 ppm CO_2 vs 80.2 ppm CO_2), reactive carbon (852 ppm vs 868.4 ppm) and Biological soil quality (4).

Site B produced 14.3 bu/ac more than site A (Site A: 206.8 bu/ac vs Site B: 221.1 bu/ac). Although the yield increase was relatively small the data does support the VitTellus and GFI predictions.

Table 8. Soil Analysis of Field 8.

	Report # C19221-10025	
Parameters	**8A**	**8B**
Yield (bu/ac)	206.8	221.1
Organic Matter (OM, %)	3.3	3.6
Phosphorus (Bicarb, ppm)	36.4	48.2
Phosphorus (Bray, ppm)	69.2	117.2
Potassium (K, ppm)	59.8	112.4
Magnesium (Mg, ppm)	118.6	217.0
Calcium (Ca, ppm)	1404.0	1214.0
Sodium (Na, ppm)	9.4	10.8
Sulfur (S, ppm)	12.8	14.8
Zinc (Zn, ppm)	2.9	2.2
Manganese (Mn, ppm)	18.6	10.8
Iron (Fe, ppm)	62.0	94.6
Copper (Cu, ppm)	0.8	1.5
Boron (B, ppm)	0.4	0.4
Aluminum (Al, ppm)	1086.0	883.6
CEC (meq/ 100g)	9.2	11.8
K/Mg Ratio	0.16	0.16
General Fertility Index (GFI)	61	72
Percent Base Saturation %K	1.7	2.5
%Mg	10.7	15.5
%Ca	76.0	51.9
%H	11.2	29.8
%Na	0.5	0.4
pH	7.0	5.5
Buffer pH	6.9	6.7
EC (ms/cm)	0.2	0.4
Saturation %P	7.4	17
Saturation %Al	0.22	1.48
Nitrate-N (ppm)	9.2	34.6
Chloride (ppm)	10.2	13.6
Potential Mineralizable Nitrogen (PMN, ppm)	42.4	42.4
Water Extracted Organic C (ppm)	94.0	182.0
Water Extracted Inorganic N (ppm)	7.0	38.9
Water Extracted Organic N (ppm)	17.0	21.1
Solvita CO2-C (ppm)	80.4	80.2
Reactive C (ppm)	852.0	868.4
Soil Health Index	32	38
%Microbial Active Carbon (MAC)	85.7	44.38
Organic C:N ratio	6.5	10.2
NRCS Soil Health Calculations	10.06	11.96
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	45	48.4
Water extracted total N	24	60
Water extracted Soil Nitrate	5.2	28.8
Water extracted Soil Ammonium	2	10.2

NRCS soil health calculations based on the Haney test results.

Microbial communities

As shown on Figure 11A, the bacterial communities of site A and B were somehow different, except for the bacterial communities of sample 8A-2 that were more similar to the communities from site B. When the outlier was removed, the differences between the bacteria from site A and B were more evident, although the differences were not statistically significant (Figure 11B).

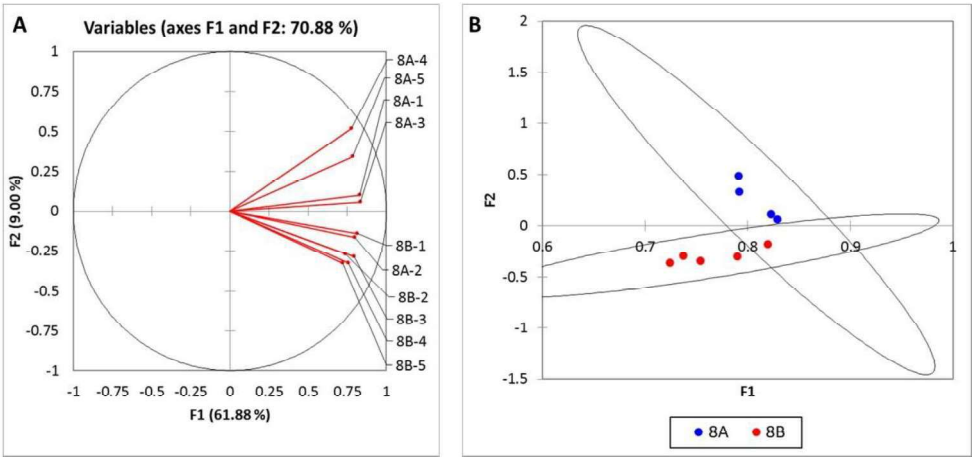

Figure 11. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 8. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

The differences in the microbial communities of roots from sites A and B were more evident when the fungi were analyzed (Figure 12). The drastic differences on soil pH between sites (Site A pH: 7; Site B pH: 5.5) are likely driving the differences between the microbial composition of roots form these sites.

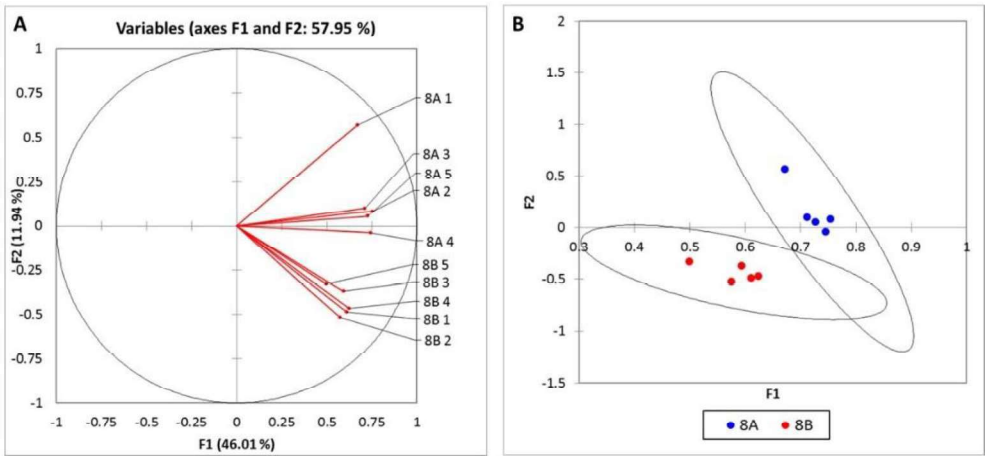

Figure 12. Statistical analysis of TRFLP of the fungal communities in corn roots of field 8. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 9

A summary of the soil chemical analysis and yield of field 9 is presented in Table 9.

Sites A and B in this field had similar chemical composition and the same amount of organic matter (3.8%). Both sites had similar general fertility index (68 and 67) and a mediocre soil health index (37 and 36). Both sites had low levels of soil respiration (44.8 ppm CO_2 vs 50.4 ppm CO_2) and similar levels of reactive carbon (724.2 ppm vs 766.6 ppm).

The main difference between these sites was the pH. Site A had a pH of 5.6 while site B had a pH of 6.2. The low pH of site A is likely reducing the productivity of that area. Site B produced 2 bu/ac more than site A (Site A: 185.1 bu/ac vs Site B: 187.2 bu/ac).
This field should have much greater yields than we observed based on GFI but not SHI.

Table 9. Soil Analysis of Field 9.

	Report # C19225-10012	
Parameters	**9A**	**9B**
Yield (bu/ac)	185.1	187.2
Organic Matter (OM, %)	3.8	3.8
Phosphorus (Bicarb, ppm)	76.4	73.4
Phosphorus (Bray, ppm)	226.0	213.1
Potassium (K, ppm)	133.2	149.4
Magnesium (Mg, ppm)	199.2	245.5
Calcium (Ca, ppm)	1246.0	1629.6
Sodium (Na, ppm)	18.6	17.5
Sulfur (S, ppm)	13.8	12.7
Zinc (Zn, ppm)	12.1	13.3
Manganese (Mn, ppm)	22.2	37.0
Iron (Fe, ppm)	109.2	97.3
Copper (Cu, ppm)	7.0	7.9
Boron (B, ppm)	0.2	0.3
Aluminum (Al, ppm)	955.4	873.9
CEC (meq/ 100g)	13.8	14.2
K/Mg Ratio	0.21	0.19
General Fertility Index (GFI)	68	67
Percent Base Saturation %K	2.5	2.7
%Mg	12.1	14.3
%Ca	45.4	57.1
%H	39.4	25.3
%Na	0.6	0.5
pH	5.6	6.2
Buffer pH	6.5	6.6
EC (ms/cm)	0.3	0.3
Saturation %P	30.4	31.5
Saturation %Al	1.26	0.73
Nitrate-N (ppm)	12.4	12.4
Chloride (ppm)	18.4	16.6
Potential Mineralizable Nitrogen (PMN, ppm)	30.3	32.3
Water Extracted Organic C (ppm)	207.6	183.2
Water Extracted Inorganic N (ppm)	14.3	16.9
Water Extracted Organic N (ppm)	27.7	27.9
Solvita CO2-C (ppm)	44.8	50.4
Reactive C (ppm)	724.2	766.6
Soil Health Index	37	36
%Microbial Active Carbon (MAC)	21.35	28.98
Organic C:N ratio	7.8	6.81
NRCS Soil Health Calculations	9.475	8.66
Biological Soil Quality	4	3.88
Estimated Nitrogen Release (ENR, lb/ac/year)	50.2	50.38
Water extracted total N	42	44.73
Water extracted Soil Nitrate	10.2	11.93
Water extracted Soil Ammonium	4.2	5.02

NRCS soil health calculations based on the Haney test results.

Field 10

A summary of the soil chemical analysis and yield of field 10 is presented in Table 10.

In this field site A had higher organic matter levels than site B (3.3% vs 2.8%). Site B had higher levels of magnesium (143.4 ppm vs 66.4 ppm) and % saturation of magnesium (11.1% vs 7.3%) than site A. A 7.3% saturation of magnesium is ranked below the optimal range for crop productivity, while 11.1% is within the optimal range.

Site B also had higher levels of calcium (1796 ppm vs 470 ppm) and % saturation of calcium (84% vs 31.1%) than site A. An 84% saturation of calcium is considered high (Site B), while a 31.1% is below the optimal range (Site A). Site B had also higher levels of boron (0.2 ppm vs 0.6 ppm) and better K/Mg ratio (0.32 vs 0.61) than site A. Our research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity.

Site A had a high % saturation of phosphorus (21%) while site B had a medium % phosphorus saturation (6.6%). Both sites had medium respiration levels (66.6 ppm CO_2 and 75 ppm CO_2), similar levels of reactive carbon (826.8 ppm vs 836.6 ppm) and soil quality (4).

Site B had higher general fertility index (GFI, 77 vs 68), and higher soil health index than site A (SHI, 42 vs 37). A SHI of 37 is considered mediocre while a SHI of 42 is considered good. Site B also had higher pH than site A (pH 7.3 vs 5.6). The acidic pH of site A is likely affecting crop productivity.

Site A and B had the same productivity (Site A: 254.6 bu/ac and Site B: 253.1 bu/ac). This site is producing at near optimal levels.

Table 10. Soil Analysis of Field 10.

	Report # C19221-10026	
Parameters	**10A**	**10B**
Yield (bu/ac)	254.6	253.1
Organic Matter (OM, %)	3.3	2.8
Phosphorus (Bicarb, ppm)	65.6	49.8
Phosphorus (Bray, ppm)	199.0	114.8
Potassium (K, ppm)	132.2	150.4
Magnesium (Mg, ppm)	66.4	143.4
Calcium (Ca, ppm)	470.0	1796.0
Sodium (Na, ppm)	12.2	10.6
Sulfur (S, ppm)	13.0	9.8
Zinc (Zn, ppm)	4.6	5.1
Manganese (Mn, ppm)	20.0	59.6
Iron (Fe, ppm)	85.2	76.2
Copper (Cu, ppm)	0.8	1.4
Boron (B, ppm)	0.2	0.6
Aluminum (Al, ppm)	1204.8	644.8
CEC (meq/ 100g)	7.6	10.7
K/Mg Ratio	0.61	0.32
General Fertility Index (GFI)	68	77
Percent Base Saturation %K	4.4	3.6
%Mg	7.3	11.1
%Ca	31.1	84.0
%H	56.4	0.9
%Na	0.7	0.4
pH	5.6	7.3
Buffer pH	6.6	
EC (ms/cm)	0.2	0.2
Saturation %P	21	8.60
Saturation %Al	2.5	0.10
Nitrate-N (ppm)	5	5.8
Chloride (ppm)	12.6	17.8
Potential Mineralizable Nitrogen (PMN, ppm)	38.4	40.8
Water Extracted Organic C (ppm)	28.4	77.2
Water Extracted Inorganic N (ppm)	5.4	6.5
Water Extracted Organic N (ppm)	27.6	23.0
Solvita CO2-C (ppm)	66.6	75.0
Reactive C (ppm)	826.8	836.6
Soil Health Index	37	42
%Microbial Active Carbon (MAC)	268.3	98.44
Organic C:N ratio	1.5	4.14
NRCS Soil Health Calculations	7.22	8.94
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	45.4	40.2
Water extracted total N	33	29.6
Water extracted Soil Nitrate	3	4.4
Water extracted Soil Ammonium	2.4	2.2

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial and fungal communities associated with roots from site A were different than those associated with plants from site B, as evident by the grouping of the samples A and B in different quadrants (Figure 13A and 14 A). Although the differences were very clear, they were not statistically significant (Figures 13B and 14B). The main driver for the differences in the microbial communities of plants from sites A and B is likely the soil pH. Site A had a pH of 5.6 while site B had a pH of 7.3.

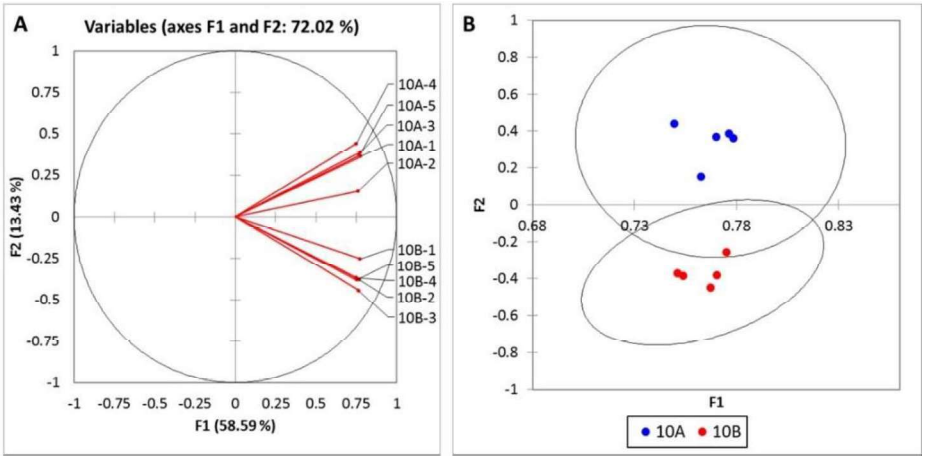

Figure 13. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 10. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

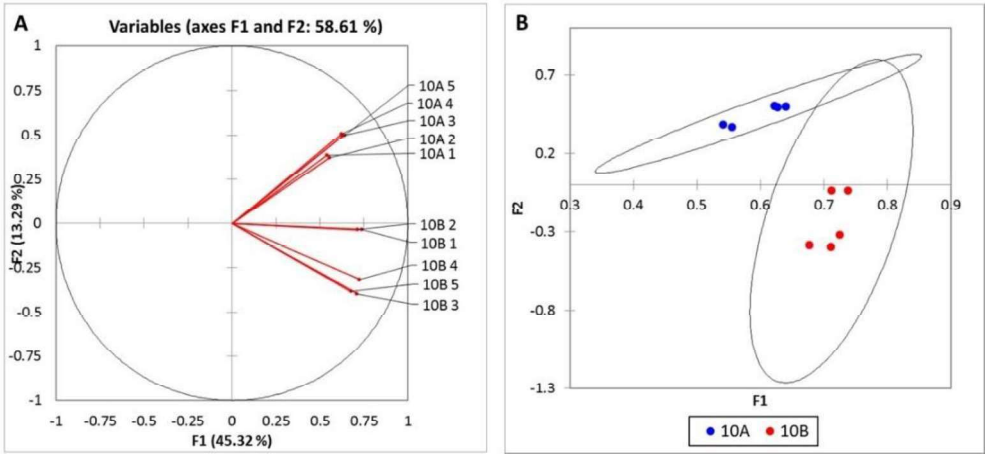

Figure 14. Statistical analysis of TRFLP of the fungal communities in corn roots of field 10. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 11

A summary of the soil chemical analysis and yield of field 11 is presented in Table 11.

In this field site A had higher levels of phosphorus (61.4 ppm vs 32.2 ppm) and % saturation of phosphorus (9.6% vs 6%) than site B. In this case both % P saturation are considered medium. Site A also had higher levels of potassium (102.6 ppm vs 87.8 ppm) and % saturation of potassium (2.2% and 1.7%) than site B. However, both % saturation of potassium were below the optimal range. Similarly, site A had a better K/Mg ratio (0.16 vs 0.12) than site B, but the K/Mg on both sites is below the optimal levels.

The GFI and the SHI of site A were higher than of site B (GFI: 67 vs 59; SHI: 35 vs 31). Both soil health indexes are considered as mediocre.

Both sites had similar soil respiration (100.8 ppm CO_2 and 98.6 ppm CO_2), reactive carbon levels (831.6 ppm vs 845.8 ppm) and soil quality (4 vs 4.4).

Site B produced 85.7 bu/ac more than site A (Site A: 136.8 bu/ac; Site B: 222.5 bu/ac). Based on the soil chemical data we are unable to identify the huge differences in productivity at these sites.

Table 11. Soil Analysis of Field 11.

	Report # C19221-10024	
Parameters	**11A**	**11B**
Yield (bu/ac)	136.8	222.5
Organic Matter (OM, %)	3.6	3.9
Phosphorus (Bicarb, ppm)	33.8	20.0
Phosphorus (Bray, ppm)	61.4	32.2
Potassium (K, ppm)	102.6	87.8
Magnesium (Mg, ppm)	194.2	228.2
Calcium (Ca, ppm)	1750.0	1976.0
Sodium (Na, ppm)	13.0	10.4
Sulfur (S, ppm)	14.0	9.8
Zinc (Zn, ppm)	3.1	3.1
Manganese (Mn, ppm)	24.2	49.6
Iron (Fe, ppm)	100.6	66.8
Copper (Cu, ppm)	3.6	3.0
Boron (B, ppm)	0.4	0.5
Aluminum (Al, ppm)	822.8	608.6
CEC (meq/ 100g)	11.9	13.2
K/Mg Ratio	0.16	0.12
General Fertility Index (GFI)	67	59
Percent Base Saturation %K	2.2	1.7
%Mg	13.6	14.4
%Ca	73.7	74.7
%H	9.9	8.8
%Na	0.5	0.3
pH	6.4	7.1
Buffer pH	6.9	
EC (ms/cm)	0.2	0.2
Saturation %P	9.6	6.0
Saturation %Al	0.36	0.10
Nitrate-N (ppm)	1	4.2
Chloride (ppm)	27.2	12.4
Potential Mineralizable Nitrogen (PMN, ppm)	47.4	46.8
Water Extracted Organic C (ppm)	216.0	190.4
Water Extracted Inorganic N (ppm)	6.6	6.8
Water Extracted Organic N (ppm)	29.4	27.2
Solvita CO2-C (ppm)	100.8	98.6
Reactive C (ppm)	831.6	845.8
Soil Health Index	35	31
%Microbial Active Carbon (MAC)	46.64	52.08
Organic C:N ratio	7.5	7.12
NRCS Soil Health Calculations	15.16	14.50
Biological Soil Quality	4	4.40
Estimated Nitrogen Release (ENR, lb/ac/year)	48.2	51.00
Water extracted total N	36	34.00
Water extracted Soil Nitrate	1.6	1.60
Water extracted Soil Ammonium	4.8	5.40

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found between the bacterial communities associated with roots from plant of site A and B (Figure 15). In contrast, the fungal communities from site A were different than the fungi associated with plants of site B, as evident by de clustering of the samples A and B in different quadrants (Figure 16 A). Statistical analysis however showed that the differences were not significant (Figure 16 B).

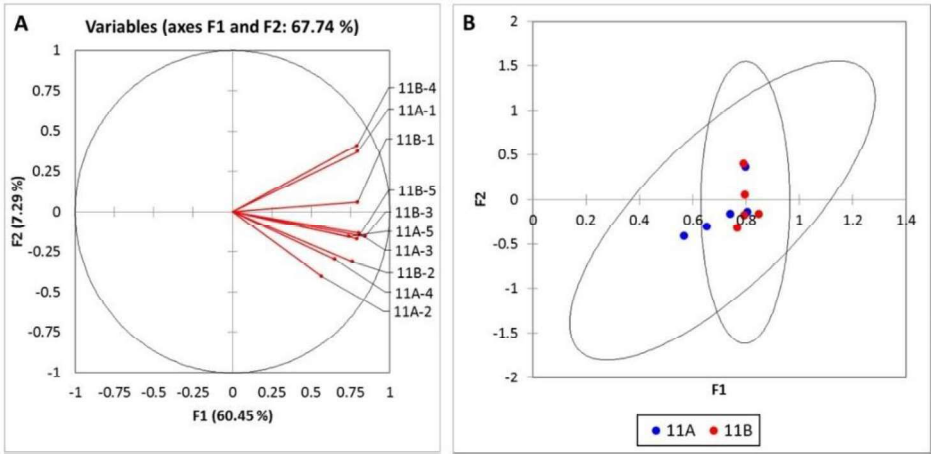

Figure 15. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 11. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

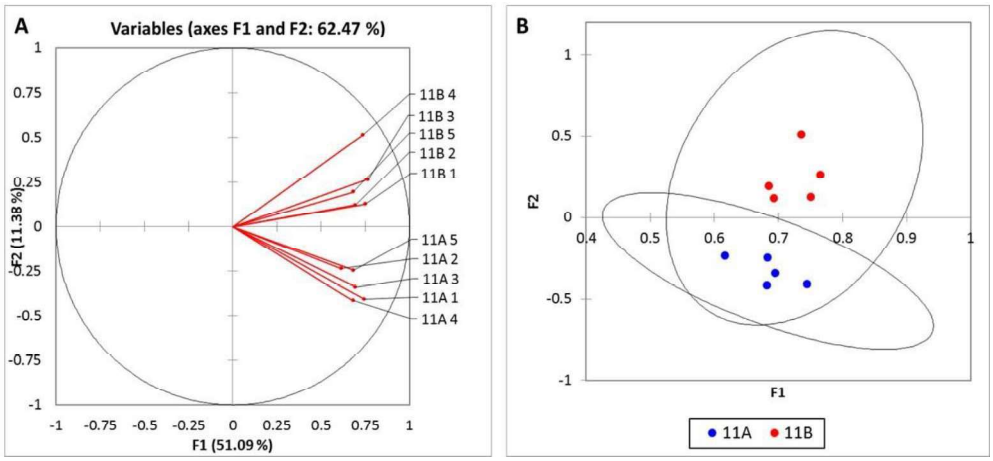

Figure 16. Statistical analysis of TRFLP of the fungal communities in corn roots of field 11. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 12

A summary of the soil chemical analysis and yield of field 12 is presented in Table 12.

The chemical composition of site A and B were very similar. Site B had higher levels of potassium (162.4 ppm vs 143.4n ppm) and % saturation of potassium than site A (3.9% vs 2%) than site A. However, considering the respective CEC (Site A: 18.5 meq/100g and Site B: 10.9 meq/100g), both % saturation of potassium were within the optimal range.

Both sites had low soil respiration (46.3 ppm CO2 vs 38.3 ppm CO2), similar reactive carbon levels (783.3 ppm vs 787.5), and identical biological soil quality (3).

Both sites had a GFI of 70 and a SHI of 38 that is considered as mediocre good. However, the low pH of this field (site A pH: 4.9 and Site B pH: 5) is affecting crop productivity.

There were no differences in the productivity of sites A and B (200.5 bu/ac and 202 bu/ac, respectively).

Table 12. Soil Analysis of Field 12.

	Report # C19231-10101	
Parameters	**12A**	**12B**
Yield (bu/ac)	200.5	202
Organic Matter (OM, %)	4.4	3.8
Phosphorus (Bicarb, ppm)	36.6	27.6
Phosphorus (Bray, ppm)	78.2	53.4
Potassium (K, ppm)	143.4	162.4
Magnesium (Mg, ppm)	157.8	82.4
Calcium (Ca, ppm)	1446.0	858.0
Sodium (Na, ppm)	10.4	8.8
Sulfur (S, ppm)	19.0	13.0
Zinc (Zn, ppm)	5.9	4.5
Manganese (Mn, ppm)	8.8	12.8
Iron (Fe, ppm)	119.4	85.0
Copper (Cu, ppm)	4.3	1.5
Boron (B, ppm)	0.4	0.2
Aluminum (Al, ppm)	964.8	892.0
CEC (meq/ 100g)	18.5	10.9
K/Mg Ratio	0.28	0.61
General Fertility Index (GFI)	70	70
Percent Base Saturation %K	2.0	3.9
%Mg	7.2	6.5
%Ca	39.3	40.5
%H	51.3	48.8
%Na	0.2	0.3
pH	4.9	5.0
Buffer pH	6.2	6.5
EC (ms/cm)	0.2	0.2
Saturation %P	10.4	7.80
Saturation %Al	2.6	3.40
Nitrate-N (ppm)	10.8	9.2
Chloride (ppm)	13.6	13.4
Potential Mineralizable Nitrogen (PMN, ppm)	30.3	27.5
Water Extracted Organic C (ppm)	256.0	154.0
Water Extracted Inorganic N (ppm)	23.1	11.8
Water Extracted Organic N (ppm)	32.2	3.5
Solvita CO2-C (ppm)	46.3	38.3
Reactive C (ppm)	783.3	787.5
Soil Health Index	38	38
%Microbial Active Carbon (MAC)	18.3	25.1
Organic C:N ratio	7.3	302.2
NRCS Soil Health Calculations	8.8	5.8
Biological Soil Quality	3	3
Estimated Nitrogen Release (ENR, lb/ac/year)	56.4	50.2
Water extracted total N	55.25	15.25
Water extracted Soil Nitrate	13.5	8.25
Water extracted Soil Ammonium	9.5	3.50

NRCS soil health calculations based on the Haney test results.

Field 13

A summary of the soil chemical analysis and yield of field 13 is presented in Table 13.

Site A had higher levels of phosphorus (66.4 ppm vs 48.2 ppm) and % saturation of phosphorus (5% vs 3.8%) than site B. For these soils, both %P saturation are considered low. Site A also had higher % saturation of potassium (3.3% vs 1.8%), and a better K/Mg ratio (0.28 vs 0.17) than site B. Both sites had high % saturation of calcium (84.7% and 86.7%). The pH of site A was 7.4 and of site B was 7.6.

In general, Site A had a more balanced fertility, as indicated by a higher GFI (74 vs 62) and a better soil health index (40 vs 33). A SHI of 40 is considered good, while a SHI of 33 is considered as mediocre.

Both sites had low respiration rates (53.6 ppm CO_2 vs 57.5 ppm CO_2). Site A had lower levels of reactive carbon than site B (691.4 ppm vs 728 ppm). According to the Cornell assessment of soil health in ppm of active carbon for a medium textured soil (Very Low 0-400, Low 400-500, Medium 500-600, High 600-700 and Very High >700), site A had high levels of reactive carbon (691.4 ppm) while site B had very high levels (728 ppm).

Site B produced 13 bu/ac more than site A (Site A: 190.3 bu/ac vs Site B: 203.3 bu/ac). Based on the better-balanced soil fertility and biology the yields at site A should have been higher than at site B. However, the yield differences are likely within the error of sampling.

Table 13. Soil Analysis of Field 13

	Report # C19221-10027	
Parameters	**13A**	**13B**
Yield (bu/ac)	190.3	203.3
Organic Matter (OM, %)	2.3	2.7
Phosphorus (Bicarb, ppm)	38.2	29.8
Phosphorus (Bray, ppm)	66.4	48.2
Potassium (K, ppm)	98.6	101.8
Magnesium (Mg, ppm)	106.8	189.0
Calcium (Ca, ppm)	1306.0	2468.0
Sodium (Na, ppm)	10.8	19.6
Sulfur (S, ppm)	12.6	20.4
Zinc (Zn, ppm)	4.6	4.5
Manganese (Mn, ppm)	50.6	120.2
Iron (Fe, ppm)	86.6	65.8
Copper (Cu, ppm)	1.9	1.8
Boron (B, ppm)	0.4	0.5
Aluminum (Al, ppm)	648.4	542.2
CEC (meq/ 100g)	7.7	14.2
K/Mg Ratio	0.28	0.17
General Fertility Index (GFI)	74	62
Percent Base Saturation %K	3.3	1.8
%Mg	11.5	11.1
%Ca	84.7	86.7
%H	0.0	0.0
%Na	0.6	0.6
pH	7.4	7.6
Buffer pH		
EC (ms/cm)	0.2	0.5
Saturation %P	5	3.8
Saturation %Al	0.1	0.00
Nitrate-N (ppm)	4.4	27.8
Chloride (ppm)	9.4	9.0
Potential Mineralizable Nitrogen (PMN, ppm)	32.8	35.0
Water Extracted Organic C (ppm)	101.6	135.2
Water Extracted Inorganic N (ppm)	5.1	27.3
Water Extracted Organic N (ppm)	12.9	24.7
Solvita CO2-C (ppm)	53.6	57.5
Reactive C (ppm)	691.4	728.0
Soil Health Index	40	33
%Microbial Active Carbon (MAC)	53.68	42.30
Organic C:N ratio	11.8	5.78
NRCS Soil Health Calculations	7.26	5.06
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	35	39.2
Water extracted total N	18	52
Water extracted Soil Nitrate	2.4	23.6
Water extracted Soil Ammonium	2.6	3.8

NRCS soil health calculations based on the Haney test results.

Field 14

A summary of the soil chemical analysis and yield of field 14 is presented in Table 14.

In this field, site B had higher levels of potassium (100.8 ppm vs 68.2 ppm) and % saturation potassium (3.1% vs 2.3%) than site A. For this soil, a 3.1% saturation of potassium is within the optimal range for crop productivity, while a 2.3% is below the optimal levels. We have identified the %K as one of the top 5 chemical factors that affect crop production.

Site B also had higher levels of magnesium (219.8 ppm vs 122.4 ppm) and % saturation of magnesium than site A (21.6% vs 13.5%). A 21.6% magnesium saturation is above the recommended range. In general, when the % saturation of magnesium is 20% or higher soils tend to become tight and anaerobic, negatively impacting yield. Due a technical error, no soil respiration could be reported for this field.

Both sites had a low K/Mg ratio (0.17 vs 0.14) and similar reactive carbon levels (772.4 ppm CO_2 vs 724.6 ppm CO_2).

Although Site B had a better general fertility index (65 vs 55) and a higher soil health index (35 vs 30) than site A, the high levels of magnesium of site B are likely reducing the productivity of this site.

Site A produced 43.2 bu/ac more than site B (Site A: 242.2 bu/ac vs Site B:199 bu/ac).

Table 14. Soil Analysis of Field 14

	Report # C19221-10028	
Parameters	**14A**	**14B**
Yield (bu/ac)	242.2	199
Organic Matter (OM, %)	2.9	2.7
Phosphorus (Bicarb, ppm)	28.4	22.0
Phosphorus (Bray, ppm)	49.6	36.6
Potassium (K, ppm)	68.2	100.8
Magnesium (Mg, ppm)	122.4	219.8
Calcium (Ca, ppm)	1228.0	1062.0
Sodium (Na, ppm)	9.0	9.6
Sulfur (S, ppm)	20.8	12.0
Zinc (Zn, ppm)	3.8	2.9
Manganese (Mn, ppm)	15.6	22.4
Iron (Fe, ppm)	78.8	63.6
Copper (Cu, ppm)	1.7	0.9
Boron (B, ppm)	0.4	0.4
Aluminum (Al, ppm)	1198.2	773.0
CEC (meq/ 100g)	7.6	8.5
K/Mg Ratio	0.17	0.14
General Fertility Index (GFI)	55	65
Percent Base Saturation %K	2.3	3.1
%Mg	13.5	21.6
%Ca	81.0	62.6
%H	2.8	12.3
%Na	0.5	0.5
pH	7.2	7.0
Buffer pH		6.9
EC (ms/cm)	0.2	0.2
Saturation %P	4	6
Saturation %Al	0.2	0.18
Nitrate-N (ppm)	2.4	2
Chloride (ppm)	15.6	20.8
Potential Mineralizable Nitrogen (PMN, ppm)		
Water Extracted Organic C (ppm)	74.4	101.2
Water Extracted Inorganic N (ppm)	3.8	3.6
Water Extracted Organic N (ppm)	9.6	12.4
Solvita CO2-C (ppm)		
Reactive C (ppm)	772.4	724.6
Soil Health Index	30	35
%Microbial Active Carbon (MAC)		
Organic C:N ratio	7.8	8.34
NRCS Soil Health Calculations	1.7	2.28
Biological Soil Quality		
Estimated Nitrogen Release (ENR, lb/ac/year)	41.4	39.40
Water extracted total N	13.6	16.00
Water extracted Soil Nitrate	1	1.00
Water extracted Soil Ammonium	3	2.60

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial and fungal communities associated with plants from site A were somehow different than those of plants of site B, although the differences were not statistically significant (Figures 17 and 18).

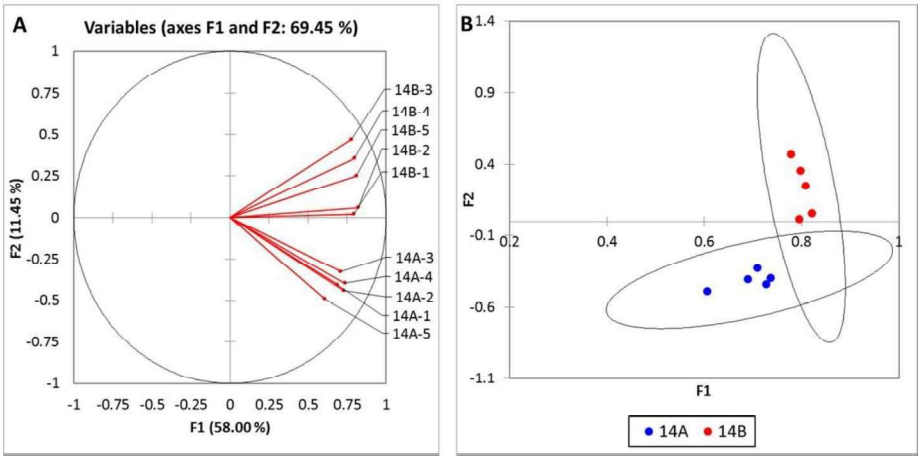

Figure 17. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 14. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

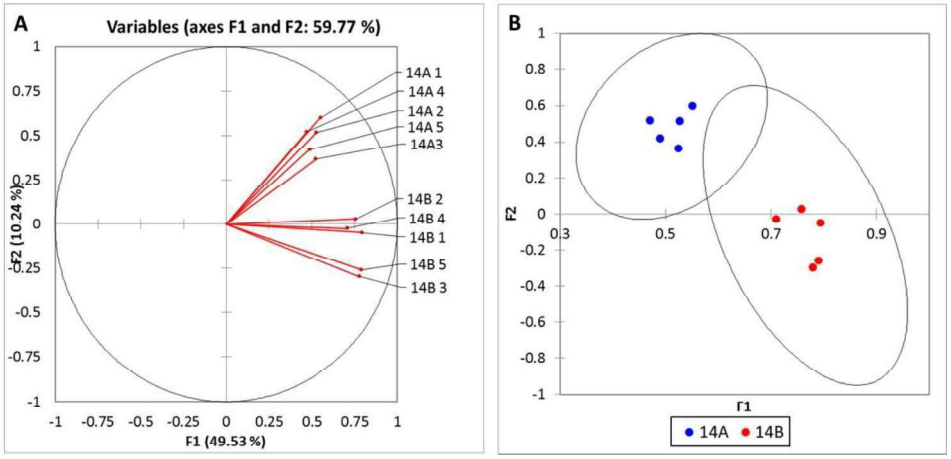

Figure 18. Statistical analysis of TRFLP of the fungal communities in corn roots of field 14. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 15

A summary of the soil chemical analysis and yield of field 15 is presented in Table 15.

In this field, sites A and B had a very low K/Mg ratio (0.09 and 0.06) and in general, low fertility (GFI 55 and 42). Site A had a slightly higher organic matter (3.1% vs 2.7%), higher levels of phosphorus (20 ppm vs 6.2 ppm), % saturation of phosphorus (3.4% vs 1%) and nitrate (61.2 ppm vs 41 pm) than site B. However, the levels of saturation of phosphorus and nitrate, for both A and B, were considered very low.

Site A had a % saturation of magnesium of 17.3 whereas site B had a % Mg of 25.6. This saturation of magnesium is above the recommended range, and at that % of Mg soils become anaerobic negatively impacting production. The soil respiration levels support this notion. Site A had a medium soil respiration while site B had a low soil respiration (61.2 ppm CO_2 vs 41 ppm CO_2).

Site A had about 100 ppm more of reactive carbon than site B (750 ppm vs 650.8 ppm) and a slightly better biological soil quality (4 vs 3.4). Similarly, site A had a higher soil health index than site B (29 vs 22), however, both soil health indexes are considered as low.

Site A produced 25 bu/ac more than site B (Site A: 106.9 bu/ac vs Site B: 81.9 bu/ac). The yields at both sites are considered well below provincial average.

Table 15. Soil Analysis of Field 15

	Report # C19225-10012	
Parameters	**15A**	**15B**
Yield (bu/ac)	106.9	81.9
Organic Matter (OM, %)	3.1	2.7
Phosphorus (Bicarb, ppm)	13.4	4.8
Phosphorus (Bray, ppm)	20.0	6.2
Potassium (K, ppm)	74.6	71.2
Magnesium (Mg, ppm)	251.4	339.6
Calcium (Ca, ppm)	1708.0	1604.0
Sodium (Na, ppm)	9.0	8.6
Sulfur (S, ppm)	13.8	8.8
Zinc (Zn, ppm)	2.2	2.0
Manganese (Mn, ppm)	35.0	27.8
Iron (Fe, ppm)	62.8	63.0
Copper (Cu, ppm)	1.4	1.4
Boron (B, ppm)	0.4	0.3
Aluminum (Al, ppm)	669.0	710.4
CEC (meq/ 100g)	12.1	11.0
K/Mg Ratio	0.09	0.06
General Fertility Index (GFI)	55	42
Percent Base Saturation %K	1.6	1.7
%Mg	17.3	25.6
%Ca	70.7	72.7
%H	10.1	0.0
%Na	0.3	0.3
pH	7.0	7.4
Buffer pH	6.9	
EC (ms/cm)	0.2	0.2
Saturation %P	3.4	1
Saturation %Al	0.1	0.1
Nitrate-N (ppm)	6	1.8
Chloride (ppm)	9.8	7.6
Potential Mineralizable Nitrogen (PMN, ppm)	35.4	28.6
Water Extracted Organic C (ppm)	171.2	163.2
Water Extracted Inorganic N (ppm)	8.1	7.5
Water Extracted Organic N (ppm)	61.9	64.5
Solvita CO2-C (ppm)	61.2	41.0
Reactive C (ppm)	750.0	650.8
Soil Health Index	29	22
%Microbial Active Carbon (MAC)	35.48	25.06
Organic C:N ratio	2.8	2.58
NRCS Soil Health Calculations	8.44	6.38
Biological Soil Quality	4	3.4
Estimated Nitrogen Release (ENR, lb/ac/year)	42.6	38.6
Water extracted total N	70	72
Water extracted Soil Nitrate	5.2	3
Water extracted Soil Ammonium	2.8	4.8

NRCS soil health calculations based on the Haney test results.

Field 16

A summary of the soil chemical analysis and yield of field 16 is presented in Table 16.

This field had high levels of organic matters as compared to the other fields studied (organic matter site A: 6%, site B: 6.8%). Sites A and B had similar chemical composition. Both sites had a very low K/Mg ratio (0.09 and 0.1), low % saturation of potassium (1.3% and 1.7%), low soil respiration rates (45.8 ppm CO_2 and 50 ppm CO_2), same soil pH (pH 6.9), and similar levels of reactive carbon (820 ppm and 845.3 ppm).

The general fertility indexes of site A and B were considered good (67 and 68, respectively), and both sites had a soil health index of 35, considered as mediocre.

The minor elements such as Cu, Mn, S, and Zn are present at very low levels and addition of these may enhance fertility.

The productivity of both sites was similar. Site A produced 7.3 bu/ac more than site B (Site A: 114.2 bu/ac vs Site B: 106.9 bu/ac).

Table 16. Soil Analysis of Field 16

	Report # C19231-10101	
Parameters	**16A**	**16B**
Yield (bu/ac)	114.2	106.9
Organic Matter (OM, %)	6.0	6.8
Phosphorus (Bicarb, ppm)	21.6	22.4
Phosphorus (Bray, ppm)	35.6	36.0
Potassium (K, ppm)	132.2	177.4
Magnesium (Mg, ppm)	446.4	508.0
Calcium (Ca, ppm)	4030.0	4028.0
Sodium (Na, ppm)	21.6	24.0
Sulfur (S, ppm)	8.2	9.2
Zinc (Zn, ppm)	4.6	3.9
Manganese (Mn, ppm)	5.2	5.0
Iron (Fe, ppm)	109.6	120.8
Copper (Cu, ppm)	4.9	5.4
Boron (B, ppm)	0.9	0.8
Aluminum (Al, ppm)	882.0	907.2
CEC (meq/ 100g)	26.5	27.1
K/Mg Ratio	0.09	0.10
General Fertility Index (GFI)	67	68
Percent Base Saturation %K	1.3	1.7
%Mg	14.1	15.7
%Ca	76.4	74.6
%H	7.9	7.7
%Na	0.4	0.4
pH	6.9	6.9
Buffer pH	6.9	6.9
EC (ms/cm)	0.2	0.2
Saturation %P	3.8	4.2
Saturation %Al	0.1	0.1
Nitrate-N (ppm)	1.6	1.4
Chloride (ppm)	6.6	7.0
Potential Mineralizable Nitrogen (PMN, ppm)	30.5	32.0
Water Extracted Organic C (ppm)	274.7	306.0
Water Extracted Inorganic N (ppm)	6.1	10.8
Water Extracted Organic N (ppm)	8.9	9.9
Solvita CO2-C (ppm)	45.8	50.0
Reactive C (ppm)	820.0	845.3
Soil Health Index	35	35
%Microbial Active Carbon (MAC)	52.18	17.23
Organic C:N ratio	35.3	174.23
NRCS Soil Health Calculations	7.25	9.03
Biological Soil Quality	4	3.7
Estimated Nitrogen Release (ENR, lb/ac/year)	73	80.8
Water extracted total N	15	20.67
Water extracted Soil Nitrate	2	4.67
Water extracted Soil Ammonium	4	6.33

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities associated with plants from site A were different than those associated with site B (Figure 19). However, the differences were not statistically significant. No differences were found on the fungal communities (Figure 20).

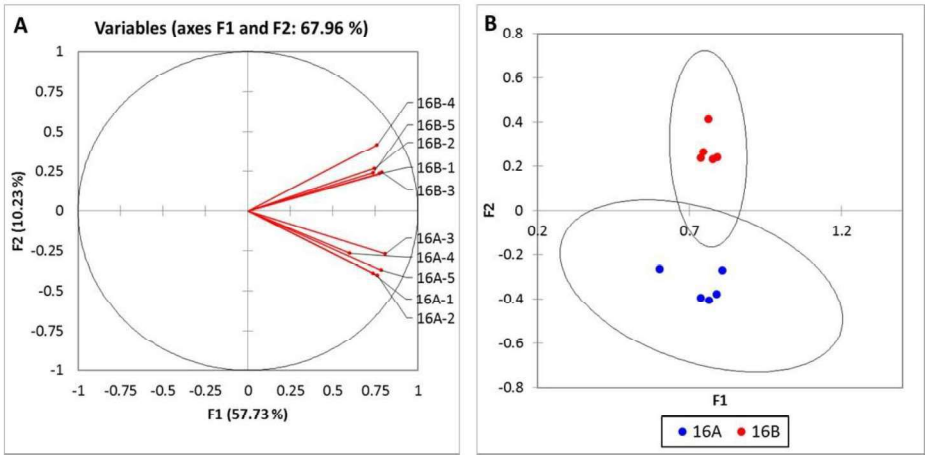

Figure 19. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 16. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

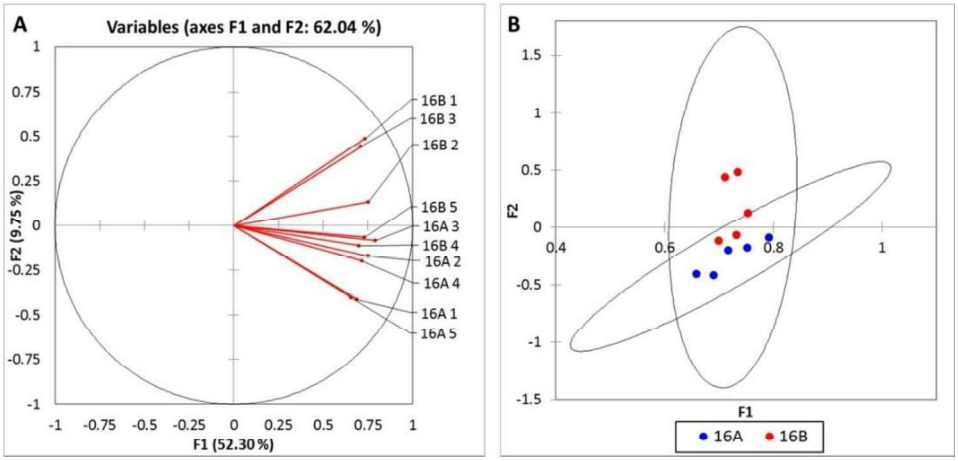

Figure 20. Statistical analysis of TRFLP of the fungal communities in corn roots of field 16. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 17

A summary of the soil chemical analysis and yield of field 17 is presented in Table 17.

Site B had a slightly higher levels of phosphorus (32.8 ppm vs 27.6 ppm), % saturation of phosphorus (4% vs 3.6%), potassium (152.2 ppm vs 146.6 ppm), and % saturation of potassium (2.2% vs 2%) than site A. In contrast, site A had higher levels of magnesium (246 ppm vs 229 ppm) and % saturation of magnesium (11.2% vs 10.8%) than site B.

Both sites had similar pH (6 and 6.1), levels of reactive carbon (822.2 ppm and 806 ppm) and soil respiration (47 ppm CO_2 and 45.8 ppm CO_2).

Site B had a better general fertility index (74 vs 68) and slightly higher soil health index SHI than site A (39 vs 36). Both the general fertility indexes and the soil health indexes are considered as mediocre.

Site A and B had similar productivity with only 7.6 bu/ac difference (Site A: 188.9 bu/ac vs Site B: 181.3 bu/ac).

Table 17. Soil Analysis of Field 17

	Report # C19225-10012	
Parameters	**17A**	**17B**
Yield (bu/ac)	188.9	181.3
Organic Matter (OM, %)	4.6	4.3
Phosphorus (Bicarb, ppm)	15.2	20.8
Phosphorus (Bray, ppm)	27.6	32.8
Potassium (K, ppm)	146.6	152.2
Magnesium (Mg, ppm)	246.0	229.0
Calcium (Ca, ppm)	2280.0	2174.0
Sodium (Na, ppm)	10.0	11.0
Sulfur (S, ppm)	10.8	8.8
Zinc (Zn, ppm)	3.5	3.1
Manganese (Mn, ppm)	41.2	21.4
Iron (Fe, ppm)	81.6	94.2
Copper (Cu, ppm)	3.0	3.1
Boron (B, ppm)	0.3	0.2
Aluminum (Al, ppm)	945.4	1045.6
CEC (meq/ 100g)	18.4	17.7
K/Mg Ratio	0.18	0.20
General Fertility Index (GFI)	68	74
Percent Base Saturation %K	2.0	2.2
%Mg	11.2	10.8
%Ca	62.2	61.4
%H	24.3	25.4
%Na	0.2	0.3
pH	6.0	6.1
Buffer pH	6.6	6.6
EC (ms/cm)	0.3	0.4
Saturation %P	3.6	4
Saturation %Al	0.48	0.5
Nitrate-N (ppm)	18.4	27.6
Chloride (ppm)	34.2	60.0
Potential Mineralizable Nitrogen (PMN, ppm)	31.0	30.2
Water Extracted Organic C (ppm)	208.4	188.0
Water Extracted Inorganic N (ppm)	18.6	12.6
Water Extracted Organic N (ppm)	39.4	37.4
Solvita CO2-C (ppm)	47.0	45.8
Reactive C (ppm)	822.2	806.0
Soil Health Index	36	39
%Microbial Active Carbon (MAC)	23.78	24.44
Organic C:N ratio	5.3	5.50
NRCS Soil Health Calculations	9.3	7.74
Biological Soil Quality	4	3.8
Estimated Nitrogen Release (ENR, lb/ac/year)	59.2	54.6
Water extracted total N	58	50.0
Water extracted Soil Nitrate	11.6	6.2
Water extracted Soil Ammonium	7.2	6.6

NRCS soil health calculations based on the Haney test results.

Field 19

A summary of the soil chemical analysis and yield of field 19 is presented in Table 18.

Both sites had similar levels of organic matter (3.8% and 3.7%), high levels of phosphorus (367.6 ppm and 328.4 ppm), high % saturation of phosphorus (32.8% and 32.4%), low % saturation of potassium (1.5% and 1.4%), and a % saturation of magnesium above the optimal range (27.2% and 24.3%). In general, soils with high Mg% become hard, from crust and become difficult to till. At a % saturation of Mg higher than 20% soils tend to become tight and anaerobic, negatively impacting production. This notion was supported by the low soil respiration rates obtained (47.2 ppm CO_2 and 41 ppm CO_2).

Our previous research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. In this field, both sites studied are considerably under that ideal range (K/Mg: 0.06).

Both sites had similar levels of reactive carbon (758 ppm and 723.2 ppm) and site A had a slightly higher biological soil quality than site B (4 vs 3.4). Site A had a pH of 6.9 while site B had a pH of 7.6, considered high.

Sites A and B had low levels of fertility (GFI 46 and 41) and poor soil health (SHI 24 and 21). Surprisingly, site B produced 104 bu/ac more than site A (Site A: 101.7 bu/ac vs Site B: 206.4 bu/ac). Based on the poor fertility of theses soils and the low soil health index, we did not anticipate 100 bu/ac difference in yields between sites, nor than site B will produce over 200 bu/ac.

Comparison of the hand harvested yields with the combine yields and a new soil sampling of sites A and B will help to clarify the effect of fertility in crop yield in this field.

Table 18. Soil Analysis of Field 19.

	Report # C19225-10012	
Parameters	**19A**	**19B**
Yield (bu/ac)	101.7	206.4
Organic Matter (OM, %)	3.8	3.7
Phosphorus (Bicarb, ppm)	128.8	116.6
Phosphorus (Bray, ppm)	367.6	328.4
Potassium (K, ppm)	91.6	109.0
Magnesium (Mg, ppm)	525.2	587.6
Calcium (Ca, ppm)	2018.0	2998.0
Sodium (Na, ppm)	15.2	11.2
Sulfur (S, ppm)	14.0	11.8
Zinc (Zn, ppm)	5.6	8.2
Manganese (Mn, ppm)	11.2	18.4
Iron (Fe, ppm)	84.4	68.2
Copper (Cu, ppm)	4.4	4.3
Boron (B, ppm)	0.2	0.5
Aluminum (Al, ppm)	1441.6	1301.0
CEC (meq/ 100g)	16.1	20.2
K/Mg Ratio	0.06	0.06
General Fertility Index (GFI)	46	41
Percent Base Saturation %K	1.5	1.4
%Mg	27.2	24.3
%Ca	62.7	74.4
%H	8.2	0.0
%Na	0.4	0.2
pH	6.9	7.6
Buffer pH	6.9	
EC (ms/cm)	0.2	0.3
Saturation %P	32.8	32.4
Saturation %Al	0.22	0.04
Nitrate-N (ppm)	2.2	3.4
Chloride (ppm)	18.4	14.2
Potential Mineralizable Nitrogen (PMN, ppm)	31.0	28.4
Water Extracted Organic C (ppm)	208.4	188.0
Water Extracted Inorganic N (ppm)	9.7	12.7
Water Extracted Organic N (ppm)	48.3	49.3
Solvita CO2-C (ppm)	47.2	41.0
Reactive C (ppm)	758	723.2
Soil Health Index	24	21
%Microbial Active Carbon (MAC)	22.76	22.28
Organic C:N ratio	4.6	3.86
NRCS Soil Health Calculations	8.74	6.46
Biological Soil Quality	4	3.4
Estimated Nitrogen Release (ENR, lb/ac/year)	50.4	49
Water extracted total N	58	62
Water extracted Soil Nitrate	4	7.2
Water extracted Soil Ammonium	5.8	5.6

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences in the bacterial and fungal communities of roots between site A and B were detected (Figures 21 and 22). Our previous research as shown that when soils have similar fertility and soil health, the differences on the root's microbiology of plants grown in such soil can not be detected using TRFLP.

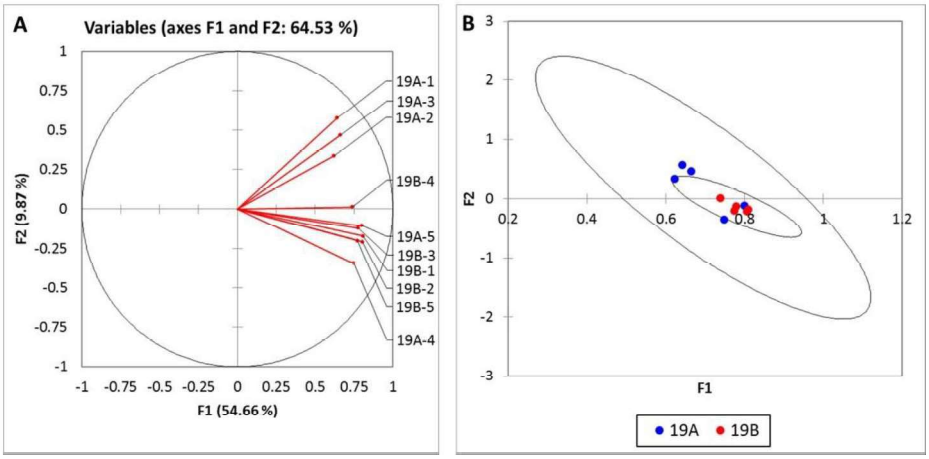

Figure 21. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 19. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

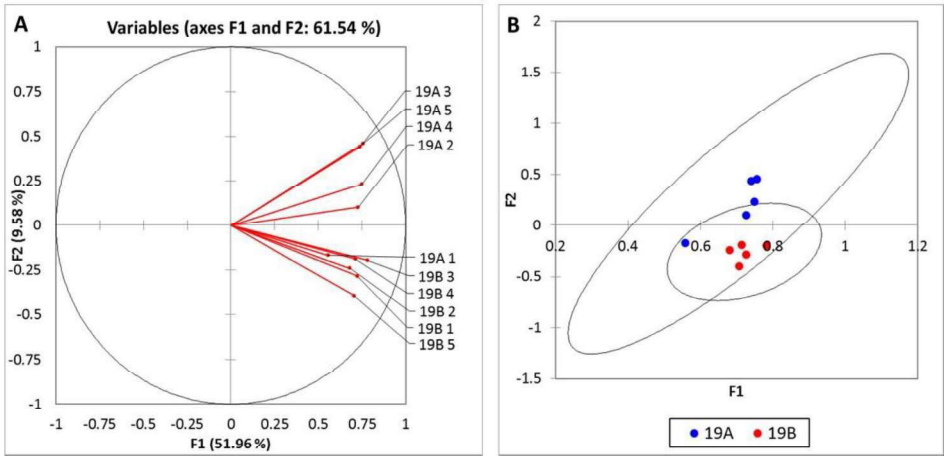

Figure 22. Statistical analysis of TRFLP of the fungal communities in corn roots of field 19. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 20

A summary of the soil chemical analysis and yield of field 20 is presented in Table 19.

In this field, site A had higher organic matter content (3.5% vs 3%), higher levels of magnesium (130.2 ppm vs 84.8 ppm), % saturation of magnesium (9.2% vs 4.9%), calcium (1546 ppm vs 602 ppm), and % saturation of calcium (65.8% vs 20.9%) than site B. The levels of calcium on site B (602 ppm) is very low.

Site A had a K/Mg ratio in the optimal range for crop productivity (0.25, optimal range: 0.25 – 0.35), while the K/Mg ration on site B was too high, and outside of the optima range (0.44). Site A also had almost double the soil respiration (Solvita 49.8 vs 28.8), and at least 200 ppm more of reactive carbon than site B (726 ppm vs 521 ppm). According to the Cornell Assessment of Soil Health in ppm of Active Carbon for a medium Textured soil, 500 ppm of reactive carbon is considered low (site B) while over 700 ppm reactive carbon is considered as very high (site A). In contrast, site A had lower levels of phosphorus and a lower % saturation of phosphorus than site B (31.2 ppm vs 71.6 ppm; and 5.2% vs 8.4%, respectively).

Site A had a more balanced fertility than site B. Site A had a general fertility index of 80, representing good fertility, while site B had a GFI of 57, representing a medium fertility. Similarly, the soil health index of site A was higher than the one from Site B (42 vs 31).

Site A had a pH of 6 while site B had a pH of 4.9. Soil pH affect the solubility of nutrients, thus their availability. Soils that have a pH of 4.9 like site B generally have low availability of calcium, magnesium, and phosphorus. At this pH, the solubility of aluminum, iron, and boron is high. Site B had very low levels of calcium (602 ppm) and low levels of magnesium (84.8 ppm) making the availability of these nutrients very low. In contrast, the soil form site B had a % saturation of aluminum considered toxic.

Surprisingly, site B produced 22.8 bu/ac more than site A (Site A: 167.8 bu/ac vs Site B: 190.6 bu/ac). Based on the chemical analysis of the soil we expected that the productivity from site A will be noticeable better than the yield form site B. There is always the possibility that the samples had been swapped my mistake either when the soil test was performed or when the yields were collected. To rule out this possibility, it will be interesting to correlate the hand harvested yield with the combine yield map. Re-sampling the soil using the GPS coordinates of site A and B is also a possibility to rule out an error when the soil analysis was performed.

Table 19. Soil Analysis of Field 20.

	Report # C19225-10012	
Parameters	**20A**	**20B**
Yield (bu/ac)	167.8	190.6
Organic Matter (OM, %)	3.5	3.0
Phosphorus (Bicarb, ppm)	17.2	33.2
Phosphorus (Bray, ppm)	31.2	71.6
Potassium (K, ppm)	107.2	122.8
Magnesium (Mg, ppm)	130.2	84.8
Calcium (Ca, ppm)	1546	602
Sodium (Na, ppm)	8.4	12.8
Sulfur (S, ppm)	7.8	11.8
Zinc (Zn, ppm)	4.6	7.2
Manganese (Mn, ppm)	95.8	81.0
Iron (Fe, ppm)	69.2	91.2
Copper (Cu, ppm)	1.2	1.4
Boron (B, ppm)	0.1	0.1
Aluminum (Al, ppm)	769	1070
CEC (meq/ 100g)	11.8	14.4
K/Mg Ratio	0.25	0.44
General Fertility Index (GFI)	80	57
Percent Base Saturation %K	2.3	2.2
%Mg	9.2	4.9
%Ca	65.8	20.9
%H	22.2	71.6
%Na	0.3	0.4
pH	6.0	4.9
Buffer pH	6.8	6.1
EC (ms/cm)	0.2	0.3
Saturation %P	5.2	8.4
Saturation %Al	0.62	3.80
Nitrate-N (ppm)	10.8	17.6
Chloride (ppm)	9.0	9.0
Potential Mineralizable Nitrogen (PMN, ppm)	32.0	22.6
Water Extracted Organic C (ppm)	117.2	103.6
Water Extracted Inorganic N (ppm)	19.3	36.2
Water Extracted Organic N (ppm)	68.7	35.8
Solvita CO2-C (ppm)	49.8	28.8
Reactive C (ppm)	726.0	521.6
Soil Health Index	42	31
%Microbial Active Carbon (MAC)	42.86	30.20
Organic C:N ratio	1.7	3.70
NRCS Soil Health Calculations	6.82	5.04
Biological Soil Quality	4	3
Estimated Nitrogen Release (ENR, lb/ac/year)	46.6	41.6
Water extracted total N	88	72
Water extracted Soil Nitrate	14.8	23.4
Water extracted Soil Ammonium	4.6	12.8

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial and fungal communities of roots of site A were different of those from site B, although the differences were not statistically significant (Figures 23 and 24).

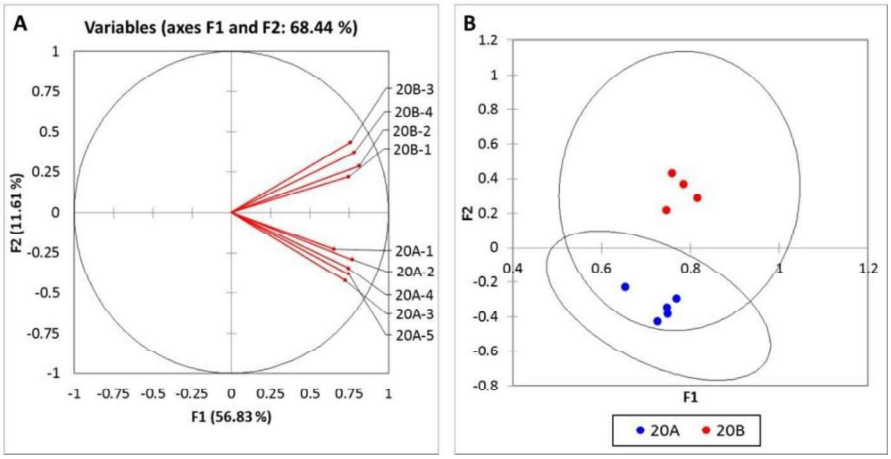

Figure 23. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 20. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

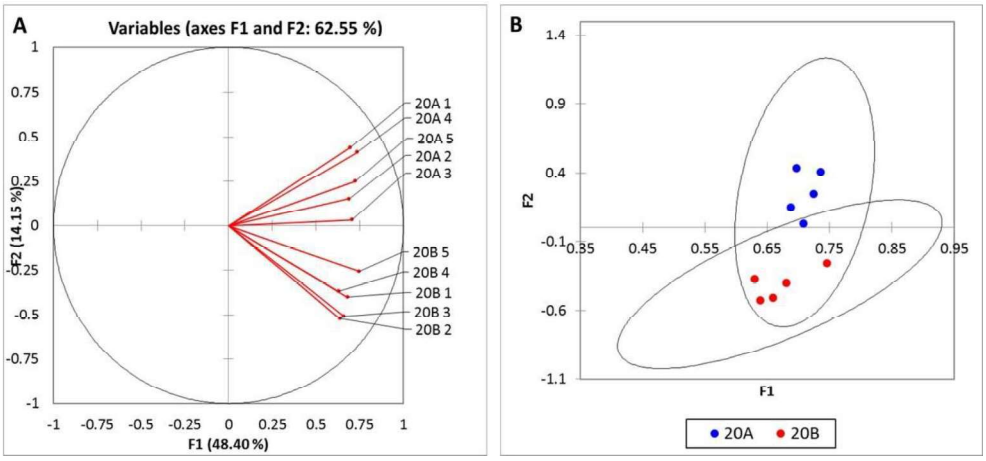

Figure 24. Statistical analysis of TRFLP of the fungal communities in corn roots of field 20. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Conclusions

The soil health test gives a complete overview of the chemical status of a soil and allows us to identify the differences between different production areas. It also provides growers with the optimal ranges of those chemical factor that highly correlate with yields and beneficial microbial activities.

Most of the fields selected for this study had uniform productivity between sites A and B. At seven of the eighteen field sampled, the differences in yield between the sites A and B were 10 bu/ac or less (fields 5, 7, 9, 12, 16, and 17); in fact, at 3 of those seven fields the differences in productivity were less than 3 bu/ac (fields 9, 10 and 12). At five of the fields studied the differences in yields between sites A and B were between 10 and 25 bu/ac (fields 3, 8, 13, 15, and 20); only at 6 fields were the differences in yield more than 25 bu/ac (fields 1, 2, 6, 11, 14, and 19). At two fields the differences in yield between A and B were about 100 bu/ac.

Out of the fields with 25 bu/ac differences in productivity between sites A and B, we were unable to identify the chemical factors that were potentially responsible for the differences in yields of fields 11, 14, 19 and 20. On **field 11**, the soil chemistry of sites A and B was very similar, with the soil from site A having a slightly more balanced soil fertility. However, site B produced over 85 bu/ac more than site B. With the available data, we were unable to explain this difference. On **field 14**, site B had a slightly better fertility than site A, however it had a % saturation of magnesium of over 20% likely making the soil anaerobic and hampering yield. Thus, site A had higher productivity than B (43 bu/ac difference). On **field 19**, the fertility of sites A and B was one of the lowest of all the fields studied, and was very similar between sites A and B. However, site B produced over 200 bu/ac and 100 bu/ac more than site B. Once again, these differences eluded us. As discussed above, there is a strong possibility that the samples A and B from **field 20** have been switched at some point during the data collection/analysis.

We did not find statistically significant differences between the microbial communities of plants grown on sites A and B on any of the fields studied, likely due to the uniformity of the selected areas. Our previous research has shown that when the difference in productivity is less than 30 bu/ac, the differences in the microbiome cannot be detected with the technology used in this study.

We carried out a correlation analysis of the soil chemical parameters as to yield and as to the soil health indexes. As shown on Table 20, a strong positive correlation was between yield (see column 1 going down, Table 20) and two factors: potassium and magnesium ratio (K/Mg) and % saturation of potassium (shown in green). In contrast, magnesium levels (Mg), % saturation of magnesium (%Mg), CEC and calcium levels were all negatively correlated to yield (shown in pink). The soil health index (SHI) was also negatively correlated with Mg levels and % saturation

of Mg, and positively correlated with K/Mg and % saturation of K (column 2, shown in green and pink, Table 20). These same factors correlated with yield although SHI did not correlate well with yield. The levels of reactive carbon, potential mineralizable nitrogen and the soil respiration (Solvita) positively correlated with the NRCS index (column 3, shown in green, Table 20).

A second analysis was conducted and this time we excluded four fields where we could not explain the impact of any soil fertility factor to yield (fields 11, 14, 19 and 20). The results shown in Table 21, indicated that the K/Mg ratio remained positively correlated to yield, as well as to the soil health index. In contrast, %Mg was negatively correlated to yield, the soil health index and the general fertility index. It is important to notice that when those fields were eliminated from the analysis, the soil health index became more highly correlated with yield, although with a relatively low p-value of 0.051619. Similarly, the levels of reactive carbon, potential mineralizable nitrogen and the soil respiration (Solvita) remained positively correlated to the NRCS index. The levels of aluminum also correlated with the NRCS index in this analysis.

Table 20. Correlation of the soil chemical parameters to yield and the calculated soil health indexes. All farms were included in this analysis.

# calculated for all farms									
# **bold/underlined** values indicate significant p-values for correlation statistic									
correlations						**p-values**			
	Yield	SHI	NRCS	GFI			Yield	SHI	NRCS	GFI
Yield	1	0.443491	-0.09828	0.403431		Yield	0	0.065261	0.698041	0.09688
SHI	0.443491	1	0.019856	**0.995028**		SHI	0.065261	0	0.937667	1.85E-17
NRCS	-0.09828	0.019856	1	0.065795		NRCS	0.698041	0.937667	0	0.795338
GFI	0.403431	**0.995028**	0.065795	1		GFI	0.09688	1.85E-17	0.795338	0
%OM	-0.41665	0.007127	0.284148	0.073458		%OM	0.085432	0.977609	0.253145	0.772066
PBray	0.178297	-0.13765	-0.02561	-0.19001		PBray	0.479041	0.585965	0.919647	0.450145
Mg	**-0.67214**	**-0.63831**	0.094287	**-0.60299**		Mg	0.002247	0.004362	0.70979	0.008075
Na	-0.34954	0.173218	0.063113	0.195506		Na	0.155071	0.491851	0.803522	0.436886
S	0.386861	0.069447	-0.30891	0.006096		S	0.112749	0.784225	0.212285	0.980849
Z	0.33027	0.104625	-0.09786	0.050603		Z	0.180717	0.679492	0.699281	0.841947
Mn	0.310595	0.239777	-0.17846	0.184732		Mn	0.209679	0.337893	0.478644	0.463049
Fe	-0.019	0.425851	0.039321	0.415232		Fe	0.940355	0.078063	0.876895	0.086607
Cu	-0.10389	-0.07886	0.178381	-0.08432		Cu	0.681632	0.755781	0.478831	0.739413
B	0.018525	0.068835	0.034484	0.059715		B	0.94184	0.786085	0.891949	0.813922
Al	-0.10736	-0.32266	-0.09411	-0.30876		Al	0.671564	0.191584	0.71031	0.212531
K/Mg	**0.588612**	**0.64062**	-0.17903	**0.582225**		K/Mg	0.010175	0.004179	0.477216	0.011239
%K	**0.533994**	**0.562471**	-0.21108	0.494719		%K	0.022451	0.015103	0.40047	0.03687
%Ca	-0.05572	-0.24939	0.015586	-0.25115		%Ca	0.826181	0.318281	0.951055	0.314766
%Na	0.366618	0.386683	-0.19777	0.350541		%Na	0.134539	0.112929	0.43148	0.153817
pH	-0.07774	-0.42773	-0.12891	-0.44924		pH	0.759131	0.076618	0.610207	0.061445
%Al	0.220336	0.367936	-0.05503	0.358187		%Al	0.379637	0.133037	0.82832	0.144426
Nitrate-N	0.26796	0.235652	0.111601	0.247069		Nitrate-N	0.282348	0.346519	0.659304	0.322952
Cl	0.095749	0.319585	0.0765	0.307303		Cl	0.705479	0.196093	0.762877	0.214804
ReaC	0.092924	0.042631	**0.506153**	0.091931		ReaC	0.713817	0.866616	0.032092	0.716754
%MAC	0.3927	0.27496	0.136749	0.267173		%MAC	0.118943	0.285477	0.600729	0.299888
%Mg	**-0.55024**	**-0.81442**	-0.0344	**-0.80356**		%Mg	0.017981	3.88E-05	0.892216	5.9E-05
K	0.14038	**0.532197**	-0.05387	0.497352		K	0.578492	0.022995	0.831861	0.035724
EC	0.280482	0.121446	0.095674	0.117309		EC	0.259586	0.631195	0.7057	0.642951
%P	0.124875	-0.03579	0.035616	-0.08002		%P	0.621514	0.887893	0.888423	0.752291
%H	0.180593	0.422168	0.010637	0.424678		%H	0.473302	0.080953	0.966588	0.078975
CEC	**-0.55464**	-0.1102	0.153687	-0.06092		CEC	0.0169	0.663353	0.542614	0.810231
Ca	**-0.50182**	-0.21928	0.151944	-0.17691		Ca	0.033842	0.381984	0.547257	0.482531
Pbicarb	0.20016	-0.1409	-0.02291	-0.19157		Pbicarb	0.42583	0.57706	0.928105	0.446346
ENR	-0.41848	0.009641	0.278497	0.075855		ENR	0.083922	0.969715	0.263116	0.764825
PMN	0.104312	0.027394	**0.805089**	0.062169		PMN	0.69032	0.916879	9.67E-05	0.812632
Solvita	0.102584	0.022983	**0.844212**	0.057778		Solvita	0.695218	0.930231	2.03E-05	0.825668
OrgC/N	0.110794	0.27643	-0.13843	0.23915		OrgC/N	0.661628	0.266823	0.583844	0.339196
WexOC	-0.39765	-0.162	0.320131	-0.13056		WexOC	0.102224	0.520716	0.195286	0.605606
WExIN	0.303701	0.258357	-0.09368	0.207658		WExIN	0.220505	0.300606	0.711577	0.408328
WExON	-0.41013	**-0.54371**	0.098895	**-0.53868**		WExON	0.090944	0.019683	0.696231	0.021082
WExTN	-0.1981	-0.34887	0.034996	-0.37429		WExTN	0.430716	0.155923	0.890352	0.125965
WExSNi	0.355612	0.286791	-0.1308	0.23016		WExSNi	0.147544	0.248565	0.60492	0.358199
WExSAm	-0.10546	0.003193	0.129349	0.006965		WExSAm	0.677068	0.989967	0.608972	0.978117

All highlighted cells show a significant correlation to yield or the soil health indexes (+ = Pink; - = green). ReaC: reactive carbon; ENR: estimated nitrogen release; OrgC/N: organic C/N ratio; WexOC: water extracted organic carbon; WExIN: water extracted inorganic nitrogen; WExON: water extracted organic nitrogen; WExTN: water extracted total nitrogen; WExSNi: water extracted soil nitrate; WExSAm: water extracted soil ammonium.

Table 21. Correlation of the soil chemical parameters to yield and the calculated soil health indexes. Farms 11, 14, 19 and 20 were excluded from this analysis.

# calculated for all farms except 11, 14, 19, 20									
# **bold/underlined** values indicate significant p-values for correlation statistic									
correlations						**p-values**			
	Yield	SHI	NRCS	GFI			Yield	SHI	NRCS	GFI
Yield	1	0.529283	0.090925	0.475941		Yield	0	0.051619	0.757222	0.085382
SHI	0.529283	1	-0.03174	**0.990483**		SHI	0.051619	0	0.914222	1.05E-11
NRCS	0.090925	-0.03174	1	0.045727		NRCS	0.757222	0.914222	0	0.876646
GFI	0.475941	**0.990483**	0.045727	1		GFI	0.085382	1.05E-11	0.876646	0
%OM	-0.39363	0.028002	0.299505	0.122527		%OM	0.163772	0.924297	0.298205	0.676468
PBray	0.366773	0.300773	-0.07876	0.221801		PBray	0.197081	0.296063	0.78897	0.446002
Mg	**-0.8128**	-0.3698	0.084399	-0.28995		Mg	0.00041	0.193133	0.774218	0.31463
Na	-0.32704	0.236092	-0.14578	0.270442		Na	0.253735	0.416447	0.618995	0.349712
S	0.360587	0.2719	-0.36162	0.180321		S	0.205319	0.347018	0.203927	0.53731
Z	0.38445	0.103039	-0.21364	0.026569		Z	0.17471	0.725945	0.463342	0.928161
Mn	0.364799	0.134136	-0.50247	0.047131		Mn	0.199686	0.647546	0.067083	0.872885
Fe	-0.00974	0.421312	-0.15087	0.405877		Fe	0.973632	0.133534	0.606677	0.14989
Cu	-0.03015	0.05203	-0.05778	0.038948		Cu	0.918514	0.859786	0.844461	0.894832
B	0.008446	0.031095	-0.28217	0.009897		B	0.977139	0.91596	0.328362	0.973212
Al	-0.03895	0.352195	**0.599825**	0.412638		Al	0.894836	0.216838	0.023359	0.14257
K/Mg	**0.654894**	**0.584588**	-0.29677	0.497152		K/Mg	0.011027	0.028122	0.302855	0.070502
%K	0.522068	0.527095	-0.3055	0.428304		%K	0.055495	0.052773	0.288158	0.126537
%Ca	-0.09652	-0.27894	-0.31783	-0.29266		%Ca	0.742736	0.33418	0.268135	0.309924
%Na	0.302079	0.392506	-0.20444	0.341124		%Na	0.293867	0.165086	0.483246	0.232638
pH	-0.10361	-0.33696	-0.35546	-0.37565		pH	0.724477	0.238752	0.212307	0.185625
%Al	0.285467	0.341469	0.107442	0.333356		%Al	0.322504	0.232135	0.714669	0.244135
Nitrate-N	0.31587	0.075587	0.421702	0.097639		Nitrate-N	0.271263	0.797319	0.133137	0.73984
Cl	0.087746	0.433869	0.021365	0.41641		Cl	0.765488	0.121147	0.942209	0.138592
ReaC	0.1072	0.097953	**0.637483**	0.167108		ReaC	0.715287	0.73903	0.01419	0.567996
%MAC	0.378174	0.269317	0.172494	0.256612		%MAC	0.182455	0.351798	0.555401	0.375834
%Mg	**-0.76178**	**-0.69412**	0.085652	**-0.66648**		%Mg	0.001544	0.005886	0.770948	0.009244
K	0.178992	**0.540582**	-0.259	0.490759		K	0.540363	0.045948	0.371257	0.074776
EC	0.331461	0.105569	0.272575	0.103242		EC	0.246992	0.719458	0.345774	0.725422
%P	0.238614	0.247645	0.009605	0.184912		%P	0.411339	0.393312	0.974002	0.52682
%H	0.237023	0.380599	0.283803	0.393139		%H	0.414559	0.179436	0.325457	0.164344
CEC	-0.50673	0.013344	0.020842	0.092913		CEC	0.06443	0.963888	0.943621	0.752062
Ca	-0.48016	-0.12144	-0.11571	-0.05802		Ca	0.082262	0.67919	0.693657	0.843813
Pbicarb	0.403647	0.332847	-0.08537	0.255834		Pbicarb	0.152357	0.244901	0.771681	0.377333
ENR	-0.39661	0.028048	0.293701	0.122442		ENR	0.160321	0.924172	0.308119	0.67668
PMN	0.128796	0.06351	**0.578938**	0.097051		PMN	0.660795	0.829227	0.03006	0.741357
Solvita	0.141587	0.070402	**0.597377**	0.103665		Solvita	0.629222	0.810986	0.02408	0.724337
OrgC/N	0.112694	0.274303	-0.3858	0.221488		OrgC/N	0.701293	0.342602	0.173072	0.44666
WexOC	-0.35879	-0.15862	-0.07859	-0.12118		WexOC	0.207755	0.588073	0.789417	0.67984
WExIN	0.40827	0.206603	-0.15688	0.130869		WExIN	0.147271	0.47853	0.592247	0.655641
WExON	-0.36189	**-0.65104**	0.095138	**-0.64545**		WExON	0.203571	0.011675	0.746303	0.012666
WExTN	-0.08133	**-0.55319**	-0.01662	**-0.60542**		WExTN	0.782257	0.040173	0.955036	0.021774
WExSNi	0.443584	0.203918	-0.20596	0.120514		WExSNi	0.112117	0.484391	0.479935	0.681526
WExSAm	-0.01576	0.124871	0.210732	0.133481		WExSAm	0.957367	0.670593	0.469584	0.649167

All highlighted cells show a significant correlation to yield or the soil health indexes (+ = Pink; - = green). ReaC: reactive carbon; ENR: estimated nitrogen release; OrgC/N: organic C/N ratio; WexOC: water extracted organic carbon; WExIN: water extracted inorganic nitrogen; WExON: water extracted organic nitrogen; WExTN: water extracted total nitrogen; WExSNi: water extracted soil nitrate; WExSAm: water extracted soil ammonium.

Appendix

The tables presented below correspond to the summary of the results of the soil chemical analysis. Values highlighted in red were considered outliers and removed from the results presented in the body of this report.

Field 1: chemical analysis

	Report # C19231-10101									
Parameters	**1A-1**	**1A-2**	**1A-3**	**1A-4**	**1A-5**	**1B-1**	**1B-2**	**1B-3**	**1B-4**	**1B-5**
Organic Matter (OM, %)	3.3	3	3.1	3.7	3.3	4.3	4.4	3.8	3.8	4.1
Phosphorus (Bicarb, ppm)	54	47	49	80	54	91	95	68	52	73
Phosphorus (Bray, ppm)	147	102	120	210	159	255	266	182	156	217
Potassium (K, ppm)	128	110	137	132	152	176	187	167	209	176
Magnesium (Mg, ppm)	267	241	239	235	253	272	255	249	242	249
Calcium (Ca, ppm)	2000	1710	1820	1960	1510	1750	1700	1660	1610	1640
Sodium (Na, ppm)	15	14	15	15	16	12	13	12	13	12
Sulfur (S, ppm)	11	11	10	13	13	12	11	10	10	11
Zinc (Zn, ppm)	4.2	3.5	4	5.2	4.4	7.2	6.9	5.1	5.2	5.5
Manganese (Mn, ppm)	27	26	23	24	26	8	9	8	7	7
Iron (Fe, ppm)	84	81	81	78	85	112	116	117	117	125
Copper (Cu, ppm)	1.3	1	1.1	1.5	1.2	2.6	2.4	2.1	2.2	2.2
Boron (B, ppm)	0.3	0.3	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4
Aluminum (Al, ppm)	727	643	687	728	730	972	956	851	848	864
CEC (meq/ 100g)	13.8	12	13.2	12.7	11.3	12.7	12.3	13.2	11.8	12
K/Mg Ratio	0.15	0.14	0.18	0.18	0.19	0.2	0.23	0.2	0.26	0.22
General Fertility Index (GFI)	64	70	74	61	71	69	74	79	76	75
Percent Base Saturation %K	2.4	2.4	2.7	2.7	3.5	3.6	3.9	3.2	4.5	3.8
%Mg	16.1	16.8	15.1	15.4	18.7	17.9	17.2	15.7	17	17.4
%Ca	72.2	71.5	68.9	76.9	66.9	69	68.9	62.7	68	68.6
%H	8.9	8.9	12.8	4.6	10.4	9.2	9.5	17.9	9.9	9.8
%Na	0.5	0.5	0.5	0.5	0.6	0.4	0.5	0.4	0.5	0.4
pH	7.1	7.1	7	7.2	6.9	6.2	6.2	6.1	6.2	6.3
Buffer pH					6.9	6.9	6.9	6.8	6.9	6.9
EC (ms/cm)	0.2	0.19	0.18	0.2	0.19	0.2	0.21	0.2	0.19	0.18
Saturation %P	26	20	22	37	28	34	36	27	24	32
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	0.4
Nitrate-N (ppm)	1	1	1	1	1	2	4	4	3	1
Chloride (ppm)	26	38	75	40	45	45	36	33	33	25
Potential Mineralizable Nitrogen (PMN, ppm)	37	39	34	38	25	39	39	33	37	37
Water Extracted Organic C (ppm)	122	142	132	144	102	100	116	116	106	108
Water Extracted Inorganic N (ppm)	3.3	1.7	1.3	5.4	1.8	2.2	3.6	2	2.7	2.3
Water Extracted Organic N (ppm)	16.7	18.3	18.7	14.6	8.2	37.8	16.4	8	17.3	7.7
Solvita CO2-C (ppm)	63	68	55	66	33	69	69	52	63	63
Reactive C (ppm)	775	736	735	772	773	846	842	805	806	842
Soil Health Index	34	37	39	32	38	37	40	42	41	40
%Microbial Active Carbon (MAC)	51.4	47.7	41.3	45.6	32.5	68.7	59.2	45.1	59.2	58.1
Organic C:N ratio	7.3	7.8	7.1	9.9	12.4	2.6	7.1	14.5	6.1	14
NRCS Soil Health Calculations	9.2	10	8.6	9.5	5.2	8.2	9.7	7.2	9.1	8.1
Biological Soil Quality	4	4	4	4	3	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	45	42	43	49	45	55	56	50	50	53
Water extracted total N	20	20	20	20	10	40	20	10	20	10
Water extracted Soil Nitrate	1	1	1	4	1	1	2	1	1	1
Water extracted Soil Ammonium	3	1	1	1	1	2	2	1	2	2

Field 2: chemical analysis

	Report # C19225-10012									
Parameters	**2A-1**	**2A-2**	**2A-3**	**2A-4**	**2A-5**	**2B-1**	**2B-2**	**2B-3**	**2B-4**	**2B-5**
Organic Matter (OM, %)	3.9	3.8	4	3.9	4	3.4	3.3	3.4	3.3	3.4
Phosphorus (Bicarb, ppm)	32	33	35	30	32	20	23	23	24	22
Phosphorus (Bray, ppm)	59	60	59	54	59	40	33	33	33	37
Potassium (K, ppm)	71	68	65	58	57	132	114	96	99	110
Magnesium (Mg, ppm)	185	182	187	181	174	209	219	220	221	233
Calcium (Ca, ppm)	2000	1990	2080	2050	1960	2180	2210	2170	2170	2250
Sodium (Na, ppm)	10	10	9	10	10	9	9	9	8	8
Sulfur (S, ppm)	9	9	9	9	10	9	9	8	8	8
Zinc (Zn, ppm)	14.3	12.7	12	11.4	12.7	10.4	9.1	9.5	10.1	10.1
Manganese (Mn, ppm)	40	39	39	38	35	67	69	64	67	71
Iron (Fe, ppm)	69	68	66	68	69	50	52	50	52	52
Copper (Cu, ppm)	3.6	3.5	3.5	3.5	3.6	4.1	4	4	4	4.2
Boron (B, ppm)	0.5	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7	0.8
Aluminum (Al, ppm)	546	544	538	564	568	548	566	554	594	613
CEC (meq/ 100g)	12.9	12.9	13.3	13.1	12.6	13	13.2	12.9	13.6	13.5
K/Mg Ratio	0.12	0.12	0.1	0.1	0.1	0.19	0.16	0.13	0.14	0.15
General Fertility Index (GFI)	65	64	65	64	64	61	57	53	58	56
Percent Base Saturation %K	1.4	1.4	1.2	1.1	1.2	2.6	2.2	1.9	1.9	2.1
%Mg	11.9	11.8	11.7	11.5	11.5	13.4	13.8	14.2	13.5	14.4
%Ca	77.2	77.3	77.9	78.1	77.7	83.9	83.8	83.8	79.8	83.4
%H	9.1	9.2	8.8	9	9.4	0	0	0	4.6	0
%Na	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
pH	6.8	6.7	6.9	6.7	6.5	7.4	7.4	7.4	7.2	7.3
Buffer pH	6.9	6.9	6.9	6.9	6.9					
EC (ms/cm)	0.23	0.23	0.25	0.24	0.28	0.24	0.24	0.21	0.22	0.24
Saturation %P	5	5	5	4	5	3	3	2	3	3
Saturation %Al	0.1	0.1	0.1	0.1	0.2	0	0	0	0.1	0.1
Nitrate-N (ppm)	8	8	10	8	13	8	8	5	6	9
Chloride (ppm)	11	9	15	14	18	18	9	9	9	8
Potential Mineralizable Nitrogen (PMN, ppm)	29	29	31	27	31	27	26	31	31	32
Water Extracted Organic C (ppm)	184	170	164	404	136		232	226	192	160
Water Extracted Inorganic N (ppm)	11.7	10.3	7.3	7.7	8.4	11.1	9.5	8.8	16.5	10.8
Water Extracted Organic N (ppm)	38.3	19.7	12.7	32.3	21.6	28.9	30.5	31.2	43.5	29.2
Solvita CO2-C (ppm)	41	41	48	38	46	36	35	46	46	50
Reactive C (ppm)	816	812	817	828	848	739	731	765	715	713
Soil Health Index	34	33	34	33	33	33	30	28	31	30
%Microbial Active Carbon (MAC)	22.5	24.4	29.1	9.4	33.5		15	20.2	23.7	31.3
Organic C:N ratio	4.8	8.6	12.9	12.5	6.3		7.6	7.2	4.4	5.5
NRCS Soil Health Calculations	6.4	7.8	7.7	11.1	8.1	3.9	8.8	9.9	6.9	9.5
Biological Soil Quality	3	3	4	3	4	3	3	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	51	50	52	51	52	46	45	46	45	46
Water extracted total N	50	30	20	40	30	40	40	40	60	40
Water extracted Soil Nitrate	10	9	6	6	7	9	7	6	14	8
Water extracted Soil Ammonium	2	1	1	2	1	2	3	3	3	3

Field 3: chemical analysis

	Report # C19231-10101									
Parameters	**3A-1**	**3A-2**	**3A-3**	**3A-4**	**3A-5**	**3B-1**	**3B-2**	**3B-3**	**3B-4**	**3B-5**
Organic Matter (OM, %)	3.4	3.6	3.5	3.5	3.3	3.7	3.8	3.5	3.7	3.6
Phosphorus (Bicarb, ppm)	26	35	22	32	38	17	25	20	32	25
Phosphorus (Bray, ppm)	52	59	44	63	66	32	39	38	65	40
Potassium (K, ppm)	109	106	94	100	102	132	163	138	129	135
Magnesium (Mg, ppm)	274	267	280	279	273	236	246	243	241	235
Calcium (Ca, ppm)	1590	1580	1650	1570	1550	2060	2120	2020	2080	1920
Sodium (Na, ppm)	14	11	11	10	12	12	12	14	12	13
Sulfur (S, ppm)	7	7	7	8	8	7	9	9	9	8
Zinc (Zn, ppm)	3.1	3.2	2.9	3.1	3.1	2.9	3.1	3.2	3.5	3.3
Manganese (Mn, ppm)	14	13	11	13	12	6	5	4	4	4
Iron (Fe, ppm)	72	75	74	73	72	93	100	101	100	101
Copper (Cu, ppm)	1.7	1.7	1.7	1.7	1.7	2.1	2.2	2.3	2.1	2.3
Boron (B, ppm)	0.4	0.5	0.4	0.4	0.4	0.3	0.4	0.3	0.4	0.4
Aluminum (Al, ppm)	664	686	674	653	641	830	880	889	881	914
CEC (meq/ 100g)	11.7	11.6	12	11.6	11.5	13.8	14.3	13.7	14	16.7
K/Mg Ratio	0.12	0.12	0.1	0.11	0.12	0.17	0.2	0.18	0.17	0.18
General Fertility Index (GFI)	63	64	62	64	68	62	70	63	67	68
Percent Base Saturation %K	2.4	2.3	2	2.2	2.3	2.4	2.9	2.6	2.4	2.1
%Mg	19.4	19.2	19.4	20	19.8	14.2	14.3	14.8	14.4	11.7
%Ca	67.7	68	68.5	67.4	67.3	74.5	74.2	73.7	74.5	57.4
%H	10	10.1	9.7	10	10.2	8.5	8.2	8.6	8.4	28.5
%Na	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.3
pH	6.6	6.3	6.6	6.5	6.4	6.7	6.3	6.2	6.2	6
Buffer pH	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.6
EC (ms/cm)	0.17	0.17	0.16	0.17	0	0.17	0.26	0.19	0	0.17
Saturation %P	10	11	8	12	13	5	6	6	9	6
Saturation %Al	0.2	0.3	0.2	0.2	0.3	0.2	0.3	0.4	0.4	0.5
Nitrate-N (ppm)	3	3	1	2	0	1	11	2	0	1
Chloride (ppm)	30	27	23	25	0	17	44	15	0	21
Potential Mineralizable Nitrogen (PMN, ppm)	36	32	34	38		29	32	29		32
Water Extracted Organic C (ppm)	96	80	116	98		140	152	178		172
Water Extracted Inorganic N (ppm)	2.8	2.9	2.2	2		3.2	6.3	4.1		7.4
Water Extracted Organic N (ppm)	47.2	7.1	17.8	8		16.8	33.7	35.9		42.6
Solvita CO2-C (ppm)	60	50	55	66		41	50	41		50
Reactive C (ppm)	786	775	818	782		730	796	696		727
Soil Health Index	33	34	32	34	36	33	38	33	35	36
%Microbial Active Carbon (MAC)	62.2	62.5	47	67		29.6	32.9	23.3		29.1
Organic C:N ratio	2	11.3	6.5	12.3		8.3	4.5	5		4
NRCS Soil Health Calculations	7.4	6.5	8.4	8.3		7.2	6.9	9.5		7.1
Biological Soil Quality	4	4	4	4		3	4	3		4
Estimated Nitrogen Release (ENR, lb/ac/year)	46	48	47	47	45	49	50	47	49	48
Water extracted total N	50	10	20	10		20	40	40		50
Water extracted Soil Nitrate	1	1	1	1		1	5	1		4
Water extracted Soil Ammonium	2	2	2	1		3	1	3		3

Field 5: chemical analysis

	Report # C19231-10101									
Parameters	**5A-1**	**5A-2**	**5A-3**	**5A-4**	**5A-5**	**5B-1**	**5B-2**	**5B-3**	**5B-4**	**5B-5**
Organic Matter (OM, %)	3.9	3.8	3.6	3.9	4.3	3	3.1	3.2	3.2	3.3
Phosphorus (Bicarb, ppm)	37	31	18	41	37	19	25	22	23	28
Phosphorus (Bray, ppm)	71	58	38	74	87	38	39	35	48	52
Potassium (K, ppm)	173	155	116	144	160	136	123	121	107	130
Magnesium (Mg, ppm)	243	237	274	242	254	223	213	226	218	215
Calcium (Ca, ppm)	1570	1550	1760	1550	1620	1380	1350	1410	1390	1380
Sodium (Na, ppm)	15	14	14	12	13	14	14	14	15	14
Sulfur (S, ppm)	10	9	9	10	11	9	9	8	9	9
Zinc (Zn, ppm)	4.6	4.5	4	5.2	7.1	3.8	3.6	3.2	3.9	3.8
Manganese (Mn, ppm)	5	6	5	5	6	7	5	6	5	5
Iron (Fe, ppm)	126	117	111	124	135	115	118	118	117	122
Copper (Cu, ppm)	2.8	2.8	3.1	2.9	3.2	1.7	1.6	1.7	1.8	1.6
Boron (B, ppm)	0.4	0.4	0.5	0.3	0.4	0.3	0.2	0.2	0.2	0.3
Aluminum (Al, ppm)	855	806	874	835	872	863	873	891	869	876
CEC (meq/ 100g)	15.2	15	13.8	13.8	15.5	12.7	13.7	12.9	11.5	16.3
K/Mg Ratio	0.22	0.2	0.13	0.18	0.2	0.18	0.18	0.16	0.15	0.18
General Fertility Index (GFI)	79	77	67	77	80	70	66	67	71	65
Percent Base Saturation %K	2.9	2.7	2.2	2.7	2.7	2.7	2.3	2.4	2.4	2
%Mg	13.4	13.2	16.5	14.7	13.7	14.6	13	14.6	15.8	11
%Ca	51.8	51.8	63.7	56.3	52.4	54.1	49.3	54.7	60.5	42.4
%H	31.5	31.9	17.2	26	30.9	28.1	34.9	27.8	20.7	44.1
%Na	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.6	0.4
pH	5.6	5.6	5.8	5.7	5.6	5.6	5.6	5.7	5.6	5.6
Buffer pH	6.6	6.6	6.8	6.7	6.6	6.7	6.6	6.7	6.8	6.4
EC (ms/cm)	0.19	0.17	0.18	0.17	0.18	0.18	0.16	0.16	0.17	0.16
Saturation %P	11	9	6	11	13	6	6	5	7	8
Saturation %Al	0.9	0.9	0.8	0.9	0.9	1.1	1.1	1	1.3	0.9
Nitrate-N (ppm)	3	1	1	1	1	3	1	1	1	1
Chloride (ppm)	13	20	15	15	18	15	15	15	16	13
Potential Mineralizable Nitrogen (PMN, ppm)	31	27	31	33	34	27	26	29	27	16
Water Extracted Organic C (ppm)	154	154	200	178	268	178	170	208	210	224
Water Extracted Inorganic N (ppm)	4.1	2.2	8.1	5.4	6.7	2.9	3.9	4.3	4	4.8
Water Extracted Organic N (ppm)	35.9	17.8	51.9	44.6	33.3	37.1	26.1	35.7	36	45.2
Solvita CO2-C (ppm)	46	38	46	52	55	38	35	41	38	18
Reactive C (ppm)	759	760	724	798	811	691	759	659	688	736
Soil Health Index	43	41	35	41	43	37	35	36	37	34
%Microbial Active Carbon (MAC)	29.6	24.7	22.8	29.4	20.3	21.4	20.4	19.9	18.1	7.8
Organic C:N ratio	4.3	8.7	3.9	4	8	4.8	6.5	5.8	5.8	5
NRCS Soil Health Calculations	6.5	7.1	7.1	7.5	11.5	6	7.8	9.8	9.5	8.5
Biological Soil Quality	4	3	4	4	4	3	3	3	3	2
Estimated Nitrogen Release (ENR, lb/ac/year)	51	50	48	51	55	42	43	44	44	45
Water extracted total N	40	20	60	50	40	40	30	40	40	50
Water extracted Soil Nitrate	1	1	1	1	5	1	1	1	1	1
Water extracted Soil Ammonium	3	2	7	4	5	2	3	3	3	4

Field 6: chemical analysis

	Report # C19218-10092									
Parameters	**6A-1**	**6A-2**	**6A-3**	**6A-4**	**6A-5**	**6B-1**	**6B-2**	**6B-3**	**6B-4**	**6B-5**
Organic Matter (OM, %)	3.7	3.9	3.7	3.7	3.6	3.2	3.2	3.3	3.2	3.1
Phosphorus (Bicarb, ppm)	177	159	166	165	170	131	113	114	111	115
Phosphorus (Bray, ppm)	515	486	498	512	497	369	344	345	336	350
Potassium (K, ppm)	284	340	350	358	339	166	171	149	151	150
Magnesium (Mg, ppm)	175	175	185	190	180	200	215	180	175	185
Calcium (Ca, ppm)	1630	1610	1650	1700	1590	2240	2260	2080	2150	2130
Sodium (Na, ppm)	12	11	13	14	13	17	19	17	14	18
Sulfur (S, ppm)	14	12	13	13	12	16	15	15	14	18
Zinc (Zn, ppm)	24.9	25.6	25.9	26.6	26.2	23.3	22.5	21.9	22	22
Manganese (Mn, ppm)	25	26	26	26	25	58	59	55	55	55
Iron (Fe, ppm)	172	163	174	162	165	148	151	150	140	146
Copper (Cu, ppm)	3.3	3.5	3.5	3.6	3.6	5.6	5.3	5.3	5.4	5.4
Boron (B, ppm)	0.5	0.5	0.5	0.6	0.6	1.1	0.8	0.9	0.8	0.8
Aluminum (Al, ppm)	813	769	791	804	736	566	556	524	503	514
CEC (meq/ 100g)	11.6	11.6	11.9	12.2	11.6	14	13.6	12.3	12.6	13.3
K/Mg Ratio	0.5	0.6	0.58	0.58	0.58	0.25	0.24	0.25	0.27	0.25
General Fertility Index (GFI)	68	66	65	69	66	68	64	64	65	68
Percent Base Saturation %K	6.3	7.5	7.5	7.5	7.5	3	3.2	3.1	3.1	2.9
%Mg	12.6	12.6	12.9	12.9	13	11.9	13.2	12.2	11.5	11.6
%Ca	70.4	69.3	69.2	69.4	68.8	79.9	83.2	84.3	85.1	80.3
%H	10.2	10.2	9.9	9.6	10.2	4.6	0	0	0	4.6
%Na	0.5	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.6
pH	6.6	6.9	6.6	6.8	6.8	7.2	7.4	7.3	7.4	7.2
Buffer pH	6.9	6.9	6.9	6.9	6.9					
EC (ms/cm)	0.22	0.21	0.22	0.22	0.21	0.25	0.25	0.24	0.24	0.25
Saturation %P	81	81	81	82	87	30	27	26	25	28
Saturation %Al	0.2	0.1	0.2	0.2	0.2	0.1	0	0.1	0	0.1
Nitrate-N (ppm)	4	4	5	4	4	4	4	4	5	3
Chloride (ppm)	29	28	34	27	23	38	24	18	29	16
Potential Mineralizable Nitrogen (PMN, ppm)	30	27	33	25	25	25	21	21	20	23
Water Extracted Organic C (ppm)	206	248	214	196	206	168	174	168	212	136
Water Extracted Inorganic N (ppm)	32.7	36.6	27.6	22.5	30.8	24.9	31	25.2	26.5	14.6
Water Extracted Organic N (ppm)	17.3	13.4	12.4	17.5	19.2	25.1	9	24.8	23.5	25.4
Solvita CO2-C (ppm)	44	37	51	34	34	33	25	26	24	30
Reactive C (ppm)	804	832	818	834	799	815	779	822	801	842
Soil Health Index	37	36	35	37	36	37	35	35	36	37
%Microbial Active Carbon (MAC)	21.3	14.8	24	17.3	16.5	19.5	14.5	15.7	11.5	21.7
Organic C:N ratio	11.9	18.5	17.3	11.2	10.7	6.7	19.3	6.8	9	5.4
NRCS Soil Health Calculations	8.2	7.5	8.5	7.1	7.4	7.5	5.2	6.8	6.9	6.9
Biological Soil Quality	4	3	4	3	3	3	4	3	3	3
Estimated Nitrogen Release (ENR, lb/ac/year)	49	51	49	49	48	44	44	45	44	43
Water extracted total N	50	50	40	40	50	50	40	50	50	40
Water extracted Soil Nitrate	30	33	24	20	27	22	27	21	23	13
Water extracted Soil Ammonium	3	4	4	3	4	3	4	4	4	2

Field 7: chemical analysis

	Report # C19218-10093									
Parameters	**7A-1**	**7A-2**	**7A-3**	**7A-4**	**7A-5**	**7B-1**	**7B-2**	**7B-3**	**7B-4**	**7B-5**
Organic Matter (OM, %)	2.5	2.7	2.5	2.5	2.3	1.6	1.8	1.7	1.7	1.7
Phosphorus (Bicarb, ppm)	55	54	61	53	58	60	58	53	54	58
Phosphorus (Bray, ppm)	125	159	142	129	133	172	156	153	141	159
Potassium (K, ppm)	116	153	141	119	135	182	182	163	198	183
Magnesium (Mg, ppm)	160	175	155	155	155	175	180	175	175	190
Calcium (Ca, ppm)	2260	2540	2320	2380	2220	1580	1660	1610	1660	1710
Sodium (Na, ppm)	14	13	11	13	12	12	12	12	12	13
Sulfur (S, ppm)	29	18	17	24	15	17	15	17	14	17
Zinc (Zn, ppm)	7.4	12.2	8.8	7.7	6.8	14.4	11.6	10.9	10.1	11.2
Manganese (Mn, ppm)	141	144	137	142	145	138	143	142	144	149
Iron (Fe, ppm)	91	94	90	87	89	89	88	88	88	90
Copper (Cu, ppm)	2.5	2.5	2.4	2.5	2.4	4.5	4.7	4.8	4.7	5.1
Boron (B, ppm)	0.9	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	1
Aluminum (Al, ppm)	588	615	611	623	639	623	630	620	631	650
CEC (meq/ 100g)	13	14.6	13.3	13.5	12.8	9.9	10.3	10	10.3	10.6
K/Mg Ratio	0.22	0.27	0.28	0.24	0.27	0.32	0.31	0.29	0.35	0.3
General Fertility Index (GFI)	68	70	69	68	71	69	73	72	72	72
Percent Base Saturation %K	2.3	2.7	2.7	2.3	2.7	4.7	4.5	4.2	4.9	4.4
%Mg	10.3	10	9.7	9.5	10.1	14.8	14.6	14.6	14.2	14.9
%Ca	87.1	87.1	87.3	87.9	86.9	80.1	80.6	80.8	80.6	80.4
%H	0	0	0	0	0	0	0	0	0	0
%Na	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5
pH	7.4	7.6	7.6	7.5	7.5	7.5	7.6	7.5	7.6	7.5
Buffer pH										
EC (ms/cm)	0.28	0.25	0.24	0.28	0.23	0.22	0.21	0.21	0.21	0.25
Saturation %P	9	12	10	9	10	14	12	12	11	13
Saturation %Al	0	0	0	0	0	0.1	0	0.1	0	0.1
Nitrate-N (ppm)	2	2	2	3	2	2	2	1	2	6
Chloride (ppm)	11	9	19	9	11	17	26	14	24	163
Potential Mineralizable Nitrogen (PMN, ppm)	23	37	32	29	29	32	26	29	32	33
Water Extracted Organic C (ppm)	156	174	146	180	222	228	286	212	236	204
Water Extracted Inorganic N (ppm)	20.7	26.7	22.3	28.1	43.8	54.7	50.8	48.5	60.8	40.2
Water Extracted Organic N (ppm)	0.3	3.3	0.7	0.9	0.2	0.3	1.2	0.5	0.2	0.8
Solvita CO2-C (ppm)	29	62	50	43	41	50	35	43	50	51
Reactive C (ppm)	746	673	636	639	607	517	466	524	460	501
Soil Health Index	37	38	38	37	38	38	40	39	40	40
%Microbial Active Carbon (MAC)	18.3	35.3	34	23.6	18.5	21.8	12.4	20	21	25.2
Organic C:N ratio	520	52.7	208.6	200	1,110	760	238.3	424	1,180	255
NRCS Soil Health Calculations	4.4	8.2	6.5	6.1	6.4	7.3	6.5	6.4	7.3	7.3
Biological Soil Quality	3	4	4	3	3	4	3	3	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	37	39	37	37	35	28	30	29	29	29
Water extracted total N	21	30	23	29	44	55	52	49	61	41
Water extracted Soil Nitrate	17	23	19	24	38	47	44	44	54	36
Water extracted Soil Ammonium	4	4	3	4	6	8	7	5	7	4

Field 8: chemical analysis

	Report # C19221-10025									
Parameters	**8A-1**	**8A-2**	**8A-3**	**8A-4**	**8A-5**	**8B-1**	**8B-2**	**8B-3**	**8B-4**	**8B-5**
Organic Matter (OM, %)	3.2	3.4	3.4	3.3	3.2	3.5	3.6	3.7	3.7	3.7
Phosphorus (Bicarb, ppm)	31	33	49	34	35	56	46	53	46	40
Phosphorus (Bray, ppm)	57	67	107	55	60	138	115	124	116	93
Potassium (K, ppm)	55	59	66	59	60	114	106	100	132	110
Magnesium (Mg, ppm)	112	122	143	112	104	219	218	220	225	203
Calcium (Ca, ppm)	1380	1380	1400	1410	1450	1180	1290	1250	1210	1140
Sodium (Na, ppm)	10	9	10	8	10	12	11	11	10	10
Sulfur (S, ppm)	13	12	13	12	14	16	16	15	13	14
Zinc (Zn, ppm)	2.9	2.8	2.7	3.2	2.9	2.2	2.2	2.2	2.3	2.2
Manganese (Mn, ppm)	17	18	19	19	20	11	10	10	12	11
Iron (Fe, ppm)	60	62	65	61	62	103	90	93	97	90
Copper (Cu, ppm)	0.8	0.7	0.8	0.8	0.8	1.6	1.6	1.5	1.4	1.4
Boron (B, ppm)	0.5	0.4	0.4	0.4	0.5	0.3	0.4	0.3	0.4	0.4
Aluminum (Al, ppm)	1058	1101	1077	1104	1090	987	854	858	895	824
CEC (meq/ 100g)	8.8	9.3	9.6	9.4	9.1	12.8	11	13.2	11.9	10.1
K/Mg Ratio	0.15	0.15	0.15	0.16	0.18	0.16	0.15	0.14	0.18	0.17
General Fertility Index (GFI)	58	61	71	59	58	66	75	66	74	78
Percent Base Saturation %K	1.6	1.6	1.8	1.6	1.7	2.3	2.5	1.9	2.8	2.8
%Mg	10.6	10.9	12.4	9.9	9.5	14.2	16.6	13.9	15.8	16.8
%Ca	78.4	74.2	73	75.2	79.4	45.9	58.8	47.5	50.9	56.5
%H	9	12.8	12.4	12.9	9	37.2	21.7	36.3	30.1	23.6
%Na	0.5	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4
pH	7.1	6.9	6.9	7	7.1	5.4	5.6	5.6	5.6	5.4
Buffer pH		6.9	6.9			6.6	6.8	6.6	6.7	6.8
EC (ms/cm)	0.23	0.25	0.25	0.24	0.25	0.35	0.44	0.35	0.52	0.54
Saturation %P	5	8	13	6	5	18	17	19	17	14
Saturation %Al	0.2	0.3	0.2	0.2	0.2	1.8	1.3	1.1	1.3	1.9
Nitrate-N (ppm)	7	11	10	9	9	22	34	22	46	49
Chloride (ppm)	8	11	11	10	11	13	13	11	16	15
Potential Mineralizable Nitrogen (PMN, ppm)	41	44	47	39	41	40	44	41	44	43
Water Extracted Organic C (ppm)	82	94	122	88	84	204	178	184	170	174
Water Extracted Inorganic N (ppm)	5.8	8.5	8	7.4	5.5	26.7	39.8	22.6	46	59.4
Water Extracted Organic N (ppm)	14.2	11.5	12	32.6	14.5	33.3	30.2	17.4	14	10.6
Solvita CO2-C (ppm)	74	86	99	69	74	71	86	76	86	82
Reactive C (ppm)	832	850	852	880	846	832	871	882	878	879
Soil Health Index	30	32	37	31	31	35	39	35	39	41
%Microbial Active Carbon (MAC)	90.2	91	81.1	78.1	88.1	34.8	48	41.5	50.3	47.3
Organic C:N ratio	5.8	8.2	10.2	2.7	5.8	6.1	5.9	10.6	12.1	16.4
NRCS Soil Health Calculations	9.6	10.6	12.3	8.1	9.7	12.5	13.4	11.2	11.7	11
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	44	46	46	45	44	47	48	49	49	49
Water extracted total N	20	20	20	40	20	60	70	40	60	70
Water extracted Soil Nitrate	3	6	7	5	5	20	30	17	34	43
Water extracted Soil Ammonium	3	3	1	2	1	7	10	6	12	16

Field 9: chemical analysis

	Report # C19225-10012									
Parameters	**9A-1**	**9A-2**	**9A-3**	**9A-4**	**9A-5**	**9B-1**	**9B-2**	**9B-3**	**9B-4**	**9B-5**
Organic Matter (OM, %)	3.9	3.8	3.8	3.7	3.9	3.9	3.9	3.9	3.9	3.7
Phosphorus (Bicarb, ppm)	81	73	86	74	68	71	74	70	71	63
Phosphorus (Bray, ppm)	247	229	251	206	197	200	209	196	209	174
Potassium (K, ppm)	154	122	129	118	143	158	180	162	177	167
Magnesium (Mg, ppm)	210	215	206	178	187	299	317	306	299	284
Calcium (Ca, ppm)	1300	1370	1220	1150	1190	1950	2290	2080	2010	2120
Sodium (Na, ppm)	17	19	20	18	19	16	17	17	15	16
Sulfur (S, ppm)	13	16	16	12	12	12	10	11	13	11
Zinc (Zn, ppm)	12.4	12.3	12.4	11.5	11.8	15.1	15.9	15	15.7	12.1
Manganese (Mn, ppm)	21	21	24	22	23	54	58	57	54	51
Iron (Fe, ppm)	109	112	113	107	105	83	85	81	81	85
Copper (Cu, ppm)	6.8	7.3	7.4	6.8	6.7	9.1	9.7	9	9.5	7.6
Boron (B, ppm)	0.2	0.2	0.2	0.1	0.1	0.5	0.5	0.4	0.5	0.5
Aluminum (Al, ppm)	940	987	993	952	905	763	794	769	762	793
CEC (meq/ 100g)	12.3	15	14.2	14.8	12.7	13.9	15.8	14.7	15	14.1
K/Mg Ratio	0.23	0.18	0.19	0.2	0.24	0.16	0.17	0.16	0.18	0.18
General Fertility Index (GFI)	75	61	61	68	74	64	64	64	70	63
Percent Base Saturation %K	3.2	2.1	2.3	2	2.9	2.9	2.9	2.8	3	3
%Mg	14.2	11.9	12.1	10	12.2	17.9	16.7	17.3	16.6	16.8
%Ca	52.9	45.6	42.9	38.9	46.7	70.2	72.5	70.5	67.1	75.2
%H	29.1	39.8	42.1	48.5	37.5	8.4	7.4	8.9	12.8	4.5
%Na	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.4	0.5
pH	5.8	5.7	5.5	5.4	5.4	6.9	6.8	7.1	7	7.2
Buffer pH	6.7	6.5	6.5	6.4	6.6	6.9	6.9			
EC (ms/cm)	0.21	0.22	0.22	0.31	0.4	0.27	0.42	0.27	0.23	0.24
Saturation %P	34	30	32	28	28	34	34	33	35	28
Saturation %Al	0.9	0.9	1.4	1.5	1.6	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	4	4	4	19	31	11	30	10	4	7
Chloride (ppm)	20	13	15	17	27	14	17	18	12	11
Potential Mineralizable Nitrogen (PMN, ppm)	29	31	30		31	32	37	36	34	33
Water Extracted Organic C (ppm)	204	216	222	200	196	154	136	172	168	140
Water Extracted Inorganic N (ppm)	4.5	6.8	5.4	19.3	35.6	14.6	30	12.2	34.5	8.4
Water Extracted Organic N (ppm)	25.5	23.2	34.6	20.7	34.4	25.4	30	27.8	35.5	21.6
Solvita CO2-C (ppm)	41	46	44		48	50	63	60	55	52
Reactive C (ppm)	749	733	716	709	714	796	847	806	830	808
Soil Health Index	41	33	33	36	40	34	34	34	38	34
%Microbial Active Carbon (MAC)	20.3	21.1	19.6		24.4	32.5	46.1	34.7	32.4	37.3
Organic C:N ratio	8	9.3	6.4	9.7	5.7	6.1	4.5	6.2	4.7	6.5
NRCS Soil Health Calculations	8.7	9	10	4.1	10.2	9.1	7.9	10.5	7.5	8.8
Biological Soil Quality	3	4	4		4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	51	50	50	49	51	51	51	51	51	49
Water extracted total N	30	30	40	40	70	40	60	40	70	30
Water extracted Soil Nitrate	2	2	2	15	30	11	28	9	17	5
Water extracted Soil Ammonium	3	5	3	4	6	4	2	3	18	3

Field 10: chemical analysis

	Report # C19221-10026									
Parameters	**10A-1**	**10A-2**	**10A-3**	**10A-4**	**10A-5**	**10B-1**	**10B-2**	**10B-3**	**10B-4**	**10B-5**
Organic Matter (OM, %)	3.4	3.3	3.2	3.5	3.3	3.1	2.8	2.4	2.9	2.9
Phosphorus (Bicarb, ppm)	61	63	65	72	67	56	49	52	46	46
Phosphorus (Bray, ppm)	181	188	205	209	212	129	110	107	122	106
Potassium (K, ppm)	121	148	122	129	141	144	170	130	171	137
Magnesium (Mg, ppm)	70	73	65	64	60	158	143	138	146	132
Calcium (Ca, ppm)	510	470	460	460	450	1790	1760	1820	1810	1800
Sodium (Na, ppm)	11	12	12	16	10	13	10	10	11	9
Sulfur (S, ppm)	16	13	11	13	12	10	9	9	11	10
Zinc (Zn, ppm)	4.3	4.3	5.1	4.4	4.8	5.3	4.8	5.1	5.2	5.1
Manganese (Mn, ppm)	19	20	20	20	21	60	58	58	63	59
Iron (Fe, ppm)	83	86	83	86	88	80	74	74	78	75
Copper (Cu, ppm)	0.8	0.8	0.8	0.8	0.8	1.3	1.3	1.4	1.4	1.4
Boron (B, ppm)	0.2	0.2	0.2	0.1	0.1	0.5	0.5	0.6	0.7	0.6
Aluminum (Al, ppm)	1197	1245	1165	1208	1209	718	615	623	648	620
CEC (meq/ 100g)	8.3	8.2	6.8	6.8	7.9	11.2	10.5	10.6	10.7	10.5
K/Mg Ratio	0.53	0.62	0.57	0.62	0.71	0.28	0.37	0.29	0.36	0.32
General Fertility Index (GFI)	66	67	72	69	66	78	79	74	78	75
Percent Base Saturation %K	3.7	4.6	4.6	4.8	4.5	3.3	4.2	3.1	4.1	3.4
%Mg	7	7.4	8	7.8	6.3	11.7	11.4	10.8	11.3	10.5
%Ca	30.8	28.7	33.8	33.7	28.3	79.8	84.2	85.8	84.3	85.9
%H	57.9	58.6	52.8	52.6	60.3	4.6	0	0	0	0
%Na	0.6	0.6	0.8	1	0.5	0.5	0.4	0.4	0.4	0.4
pH	5.7	5.6	5.7	5.6	5.6	7.2	7.4	7.4	7.3	7.4
Buffer pH	6.6	6.6	6.7	6.7	6.6					
EC (ms/cm)	0.21	0.19	0.15	0.19	0.19	0.23	0.21	0.21	0.23	0.21
Saturation %P	19	19	23	22	22	10	8	8	9	8
Saturation %Al	2.1	2.5	2.4	3	2.5	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	6	6	2	5	6	7	6	5	6	5
Chloride (ppm)	14	13	11	13	12	14	18	16	22	19
Potential Mineralizable Nitrogen (PMN, ppm)	41	35	41	39	36	40	40	38	46	40
Water Extracted Organic C (ppm)	32	28	40	30	12	70	70	94	86	66
Water Extracted Inorganic N (ppm)	6.9	6.3	4	3.3	6.7	8.2	6.9	5.3	7.8	4.5
Water Extracted Organic N (ppm)	36.1	36.7	10	18.7	36.3	11.8	36.1	27.2	12.2	27.5
Solvita CO2-C (ppm)	74	57	74	69	59	71	71	66	96	71
Reactive C (ppm)	829	821	802	847	835	840	838	824	847	834
Soil Health Index	36	37	39	37	36	42	43	40	42	41
%Microbial Active Carbon (MAC)	231.3	202.9	185	229	493.3	101.4	101.4	70.5	111.3	107.6
Organic C:N ratio	0.9	0.8	4	1.6	0.3	5.9	1.9	3.5	7	2.4
NRCS Soil Health Calculations	8.1	6.3	7.9	7.4	6.4	9	8.2	7.8	11.7	8
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	46	45	44	47	45	43	40	36	41	41
Water extracted total N	43	43	14	22	43	20	43	33	20	32
Water extracted Soil Nitrate	4	4	1	2	4	7	4	3	5	3
Water extracted Soil Ammonium	3	2	3	1	3	1	3	2	3	2

Field 11: chemical analysis

	Report # C19221-10024									
Parameters	**11A-1**	**11A-2**	**11A-3**	**11A-4**	**11A-5**	**11B-1**	**11B-2**	**11B-3**	**11B-4**	**11B-5**
Organic Matter (OM, %)	3.4	3.8	3.7	3.7	3.5	3.8	4.1	3.8	3.9	3.9
Phosphorus (Bicarb, ppm)	38	31	32	34	34	24	21	16	25	14
Phosphorus (Bray, ppm)	76	56	65	55	55	35	35	24	39	28
Potassium (K, ppm)	102	109	103	100	99	93	86	88	82	90
Magnesium (Mg, ppm)	191	201	200	192	187	220	225	228	236	232
Calcium (Ca, ppm)	1670	1800	1790	1720	1770	1820	2040	1950	2020	2050
Sodium (Na, ppm)	13	14	12	13	13	10	11	10	10	11
Sulfur (S, ppm)	16	15	13	14	12	9	10	10	11	9
Zinc (Zn, ppm)	3.7	2.9	3.2	3	2.9	3.1	3.4	2.7	3.2	3.3
Manganese (Mn, ppm)	23	26	25	25	22	46	50	50	49	53
Iron (Fe, ppm)	94	104	102	107	96	67	66	65	67	69
Copper (Cu, ppm)	3.2	3.9	3.6	3.6	3.5	3	3.1	2.9	3	3
Boron (B, ppm)	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.5	0.5	0.6
Aluminum (Al, ppm)	822	840	817	840	795	621	602	604	606	610
CEC (meq/ 100g)	11.4	12.2	12.1	11.7	11.9	12.9	13.6	12.5	13.5	13.7
K/Mg Ratio	0.17	0.17	0.16	0.16	0.16	0.13	0.12	0.12	0.11	0.12
General Fertility Index (GFI)	70	67	68	65	66	63	60	54	60	58
Percent Base Saturation %K	2.3	2.3	2.2	2.2	2.1	1.9	1.6	1.8	1.6	1.7
%Mg	13.9	13.7	13.8	13.7	13.1	14.2	13.8	15.2	14.5	14.1
%Ca	73	73.8	73.9	73.6	74.4	70.7	75.3	78.1	74.7	74.9
%H	10.3	9.7	9.7	10.1	9.9	12.9	8.9	4.6	8.9	8.9
%Na	0.5	0.5	0.4	0.5	0.5	0.3	0.4	0.3	0.3	0.3
pH	6.5	6.4	6.3	6.3	6.3	7	7.1	7.2	7.1	7.1
Buffer pH	6.9	6.9	6.9	6.9	6.9					
EC (ms/cm)	0.21	0.21	0.2	0.2	0.19	0.2	0.21	0.21	0.22	0.21
Saturation %P	12	9	10	8	9	7	7	2	8	6
Saturation %Al	0.3	0.3	0.4	0.4	0.4	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	1	1	1	1	1	4	4	4	5	4
Chloride (ppm)	59	23	21	16	17	12	14	11	12	13
Potential Mineralizable Nitrogen (PMN, ppm)	47	48	48	47	47	43	48	48	47	48
Water Extracted Organic C (ppm)	214	212	216	222	216	186	176	186	216	188
Water Extracted Inorganic N (ppm)	8.9	5.3	5.2	6.36	7.2	8.8	4.5	4.1	7.8	8.8
Water Extracted Organic N (ppm)	31.1	24.7	34.8	23.64	32.8	21.2	25.5	25.9	32.2	31.2
Solvita CO2-C (ppm)	99	105	102	99	99	82	105	102	99	105
Reactive C (ppm)	886	847	813	791	821	831	862	864	832	840
Soil Health Index	37	35	36	34	35	33	31	28	31	31
%Microbial Active Carbon (MAC)	46.2	49.5	47.2	44.5	45.8	44.2	59.7	54.8	45.8	55.9
Organic C:N ratio	6.9	8.6	6.2	9.4	6.6	8.8	6.9	7.2	6.7	6
NRCS Soil Health Calculations	15.1	15.1	15.8	14.5	15.3	12.2	14.8	14.7	15.3	15.5
Biological Soil Quality	4	5	4	4	4	4	5	4	4	5
Estimated Nitrogen Release (ENR, lb/ac/year)	46	50	49	49	47	50	53	50	51	51
Water extracted total N	40	30	40	30	40	30	30	30	40	40
Water extracted Soil Nitrate	1	2	1	2	2	1	2	1	2	2
Water extracted Soil Ammonium	8	3	4	4	5	8	3	3	6	7

Field 12: chemical analysis

	Report # C19231-10101									
Parameters	**12A-1**	**12A-2**	**12A-3**	**12A-4**	**12A-5**	**12B-1**	**12B-2**	**12B-3**	**12B-4**	**12B-5**
Organic Matter (OM, %)	4.4	4.8	4.3	4.4	4.2	3.9	3.7	3.9	3.8	3.8
Phosphorus (Bicarb, ppm)	36	33	35	40	39	37	33	22	27	19
Phosphorus (Bray, ppm)	85	77	78	73	78	76	63	45	45	38
Potassium (K, ppm)	134	165	120	154	144	137	179	155	160	181
Magnesium (Mg, ppm)	162	159	157	160	151	81	76	81	84	90
Calcium (Ca, ppm)	1440	1520	1410	1450	1410	870	830	880	840	870
Sodium (Na, ppm)	10	12	9	11	10	9	8	8	11	8
Sulfur (S, ppm)	17	22	25	16	15	19	14	9	14	9
Zinc (Zn, ppm)	6.2	6.9	5.2	5.1	6.3	5.2	4.9	3.9	4.6	3.9
Manganese (Mn, ppm)	9	10	8	8	9	14	14	12	12	12
Iron (Fe, ppm)	129	123	113	112	120	88	89	84	84	80
Copper (Cu, ppm)	4.4	4.4	4.3	4.1	4.2	1.5	1.5	1.5	1.5	1.5
Boron (B, ppm)	0.3	0.4	0.4	0.4	0.3	0.2	0.2	0.3	0.2	0.3
Aluminum (Al, ppm)	976	1013	939	925	971	888	908	873	904	887
CEC (meq/ 100g)	19.7	21.4	15.9	18.6	17.1	12.6	10.1	7.9	12.5	11.6
K/Mg Ratio	0.25	0.32	0.23	0.29	0.3	0.52	0.73	0.59	0.59	0.62
General Fertility Index (GFI)	67	66	74	71	72	67	71	80	63	67
Percent Base Saturation %K	1.7	2	1.9	2.1	2.2	2.8	4.6	5	3.3	4
%Mg	6.8	6.2	8.2	7.2	7.4	5.4	6.3	8.5	5.6	6.5
%Ca	36.5	35.5	44.4	39	41.2	34.5	41.2	55.7	33.5	37.5
%H	54.7	56	45.2	51.5	49	57	47.6	30.3	57.3	51.7
%Na	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.3
pH	5	4.8	5	4.8	4.9	5	4.9	5.1	4.9	5.3
Buffer pH	6.1	6	6.4	6.2	6.3	6.4	6.6	6.8	6.4	6.5
EC (ms/cm)	0.27	0.33	0.35	0	0.28	0.25	0.29	0.23	0	0.21
Saturation %P	11	10	11	10	10	11	9	7	6	6
Saturation %Al	2.1	2.7	2.5	2.9	2.8	3	4.4	4	3.6	2
Nitrate-N (ppm)	10	14	17	0	13	8	17	12	0	9
Chloride (ppm)	18	19	13	0	18	16	23	12	0	16
Potential Mineralizable Nitrogen (PMN, ppm)	40	25	28		28	25	27	29		29
Water Extracted Organic C (ppm)	238	258	264		264	134	150	174		158
Water Extracted Inorganic N (ppm)	10.9	20.3	42.2		18.9	8.4	19.3	10.8		8.6
Water Extracted Organic N (ppm)	0.1	29.7	27.8		71.1	11.6	0.7	0.2		1.4
Solvita CO2-C (ppm)	72	33	40		40	33	38	41		41
Reactive C (ppm)	787	808	780		758	792	767	779		812
Soil Health Index	36	36	39	38	39	36	38	43	34	37
%Microbial Active Carbon (MAC)	30.1	12.8	15.1		15.1	24.7	25.4	23.8		26.3
Organic C:N ratio	2,380	8.7	9.5		3.7	11.6	214.3	870		112.9
NRCS Soil Health Calculations	9.6	8.9	9.4		7.3	5.8	5.4	5.9		5.9
Biological Soil Quality	4	3	3		3	3	3	3		3
Estimated Nitrogen Release (ENR, lb/ac/year)	56	61	55	56	54	51	49	51	50	50
Water extracted total N	11	50	70		90	20	20	11		10
Water extracted Soil Nitrate	8	15	19		12	5	16	7		5
Water extracted Soil Ammonium	3	5	23		7	3	3	4		4

Field 13: chemical analysis

	Report # C19221-10027									
Parameters	**13A-1**	**13A-2**	**13A-3**	**13A-4**	**13A-5**	**13B-1**	**13B-2**	**13B-3**	**13B-4**	**13B-5**
Organic Matter (OM, %)	2.3	2.1	2.3	2.4	2.4	2.6	2.8	2.6	2.8	2.8
Phosphorus (Bicarb, ppm)	38	38	33	41	41	30	32	31	31	25
Phosphorus (Bray, ppm)	64	62	65	70	71	45	49	49	50	48
Potassium (K, ppm)	90	91	101	99	112	93	102	104	111	99
Magnesium (Mg, ppm)	101	105	109	112	107	180	186	188	204	187
Calcium (Ca, ppm)	1240	1300	1310	1320	1360	2420	2430	2540	2580	2370
Sodium (Na, ppm)	10	11	11	12	10	18	19	19	21	21
Sulfur (S, ppm)	13	12	13	13	12	21	18	17	27	19
Zinc (Zn, ppm)	4.7	4.4	4.6	4.7	4.7	4.4	4.5	4.5	4.8	4.5
Manganese (Mn, ppm)	58	61	63	6.2	65	115	121	122	123	120
Iron (Fe, ppm)	83	86	87	87	90	66	65	65	68	65
Copper (Cu, ppm)	1.9	1.8	1.9	2.1	1.9	1.8	1.8	1.8	2	1.8
Boron (B, ppm)	0.4	0.3	0.4	0.4	0.3	0.3	0.5	0.5	0.6	0.4
Aluminum (Al, ppm)	617	653	657	663	652	553	543	529	549	537
CEC (meq/ 100g)	7.3	7.6	7.8	7.8	8	13.9	14	14.6	15	13.7
K/Mg Ratio	0.28	0.27	0.28	0.27	0.32	0.16	0.17	0.17	0.17	0.16
General Fertility Index (GFI)	72	72	74	75	75	62	64	64	62	60
Percent Base Saturation %K	3.2	3.1	3.3	3.2	3.6	1.7	1.9	1.8	1.9	1.8
%Mg	11.5	11.4	11.7	11.9	11.1	10.8	11.1	10.7	11.4	11.3
%Ca	84.9	85	84.5	84.3	84.9	87.1	86.6	87	86.3	86.3
%H	0	0	0	0	0	0	0	0	0	0
%Na	0.6	0.6	0.6	0.7	0.5	0.6	0.6	0.6	0.6	0.7
pH	7.3	7.4	7.4	7.3	7.4	7.7	7.7	7.7	7.4	7.6
Buffer pH										
EC (ms/cm)	0.21	0.21	0.2	0.22	0.19	0.3	0.29	0.33	0.92	0.43
Saturation %P	5	5	5	5	5	3	4	4	4	4
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0
Nitrate-N (ppm)	5	5	3	6	3	7	7	13	86	26
Chloride (ppm)	7	6	8	19	7	7	9	9	10	10
Potential Mineralizable Nitrogen (PMN, ppm)	39	19	34	38	34	33	37			
Water Extracted Organic C (ppm)	94	112	100	108	94	128	144	152	122	130
Water Extracted Inorganic N (ppm)	6.5	5.3	4.4	5.4	3.8	8.9	8	13	81.9	24.5
Water Extracted Organic N (ppm)	23.5	4.7	5.6	14.6	16.2	21.1	32	27	28.1	15.5
Solvita CO2-C (ppm)	69	23	55	66	55	51	64			
Reactive C (ppm)	715	704	686	651	701	704	727	725	753	731
Soil Health Index	39	39	40	40	41	33	34	34	33	32
%Microbial Active Carbon (MAC)	73.1	20.4	55	61.4	58.5	40.2	44.4			
Organic C:N ratio	4	23.8	17.9	7.4	5.8	6.1	4.5	5.6	4.3	8.4
NRCS Soil Health Calculations	8	3.9	7.1	9.2	8.1	8.5	8.2	4.2	1.5	2.9
Biological Soil Quality	4	3	4	4	4	4	4			
Estimated Nitrogen Release (ENR, lb/ac/year)	35	33	35	36	36	38	40	38	40	40
Water extracted total N	30	10	10	20	20	30	40	40	110	40
Water extracted Soil Nitrate	3	3	2	2	2	5	5	9	78	21
Water extracted Soil Ammonium	4	2	2	3	2	4	3	4	4	4

Field 14: chemical analysis

	Report # C19221-10028									
Parameters	**14A-1**	**14A-2**	**14A-3**	**14A-4**	**14A-5**	**14B-1**	**14B-2**	**14B-3**	**14B-4**	**14B-5**
Organic Matter (OM, %)	3	2.9	3	2.9	2.9	2.8	2.8	2.8	2.6	2.7
Phosphorus (Bicarb, ppm)	38	24	23	25	32	21	20	22	28	19
Phosphorus (Bray, ppm)	63	41	43	44	57	35	32	29	49	38
Potassium (K, ppm)	73	61	64	67	76	90	109	107	103	95
Magnesium (Mg, ppm)	135	119	115	123	120	223	248	213	221	194
Calcium (Ca, ppm)	1390	1210	1140	1190	1210	1090	1090	1050	1070	1010
Sodium (Na, ppm)	9	8	9	10	9	10	11	10	9	8
Sulfur (S, ppm)	27	18	16	21	22	14	14	12	11	9
Zinc (Zn, ppm)	4.1	3.6	3.4	3.7	4.1	2.8	2.9	3.1	2.7	3.2
Manganese (Mn, ppm)	18	16	14	14	16	22	24	22	23	21
Iron (Fe, ppm)	81	81	77	75	80	68	66	63	62	59
Copper (Cu, ppm)	1.7	1.7	1.6	1.8	1.7	0.9	1	0.9	0.8	0.8
Boron (B, ppm)	0.4	0.3	0.3	0.4	0.4	0.3	0.4	0.4	0.4	0.4
Aluminum (Al, ppm)	1216	1220	1195	1161	1199	801	795	732	789	748
CEC (meq/ 100g)	8.3	7.2	7.2	7.5	7.6	8.7	8.6	8.4	8.6	8.1
K/Mg Ratio	0.17	0.16	0.17	0.17	0.2	0.13	0.14	0.16	0.14	0.15
General Fertility Index (GFI)	53	52	56	54	62	64	62	66	67	66
Percent Base Saturation %K	2.3	2.2	2.3	2.3	2.6	2.7	3.3	3.3	3.1	3
%Mg	13.6	13.7	13.3	13.6	13.1	21.4	24	21.1	21.4	19.9
%Ca	83.9	83.8	79.3	79	79.2	62.7	63.4	62.4	62.3	62.2
%H	0	0	4.6	4.6	4.6	12.8	8.8	12.8	12.8	14.5
%Na	0.5	0.5	0.5	0.6	0.5	0.5	0.6	0.5	0.5	0.4
pH	7.3	7.3	7.2	7.2	7.2	7	7.1	7	7	6.9
Buffer pH										6.9
EC (ms/cm)	0.26	0.21	0.2	0.22	0.22	0.19	0.19	0.18	0.17	0.16
Saturation %P	5	3	3	4	5	5	5	5	8	7
Saturation %Al	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Nitrate-N (ppm)	4	2	2	2	2	2	2	2	2	2
Chloride (ppm)	20	14	15	13	16	22	18	17	22	25
Potential Mineralizable Nitrogen (PMN, ppm)										
Water Extracted Organic C (ppm)	62	94	102	56	58	110	76	68	130	122
Water Extracted Inorganic N (ppm)	3.2	3.5	3.5	4	5	4.5	3.4	3.3	3.5	3.3
Water Extracted Organic N (ppm)	9.8	9.5	9.5	9.5	9.5	9.5	9.6	9.7	16.5	16.7
Solvita CO2-C (ppm)										
Reactive C (ppm)	791	777	752	770	772	739	688	721	746	729
Soil Health Index	28	28	30	29	33	34	33	35	36	35
%Microbial Active Carbon (MAC)										
Organic C:N ratio	6.3	9.9	10.7	5.9	6.1	11.6	7.9	7	7.9	7.3
NRCS Soil Health Calculations	1.6	1.9	2	1.5	1.5	2.1	1.7	1.7	3	2.9
Biological Soil Quality										
Estimated Nitrogen Release (ENR, lb/ac/year)	42	41	42	41	41	40	40	40	38	39
Water extracted total N	13	13	13	14	15	14	13	13	20	20
Water extracted Soil Nitrate	1	1	1	1	1	1	1	1	1	1
Water extracted Soil Ammonium	2	3	3	3	4	4	2	2	3	2

Field 15: chemical analysis

	Report # C19225-10012									
Parameters	**15A-1**	**15A-2**	**15A-3**	**15A-4**	**15A-5**	**15B-1**	**15B-2**	**15B-3**	**15B-4**	**15B-5**
Organic Matter (OM, %)	3	3	3	3.2	3.1	2.8	2.6	2.7	2.7	2.5
Phosphorus (Bicarb, ppm)	16	8	17	9	17	5	4	4	5	6
Phosphorus (Bray, ppm)	23	13	24	16	24	6	5	5	6	9
Potassium (K, ppm)	72	70	70	73	88	69	60	65	81	81
Magnesium (Mg, ppm)	243	246	258	244	266	344	344	331	350	329
Calcium (Ca, ppm)	1700	1700	1820	1620	1700	1620	1640	1580	1570	1610
Sodium (Na, ppm)	10	9	9	9	8	8	9	8	8	10
Sulfur (S, ppm)	13	14	14	14	14	9	9	8	9	9
Zinc (Zn, ppm)	2.4	2.1	2.2	2.1	2.2	1.9	1.7	1.8	2.4	2.1
Manganese (Mn, ppm)	34	35	37	34	35	29	26	27	30	27
Iron (Fe, ppm)	62	62	64	61	65	61	62	61	60	71
Copper (Cu, ppm)	1.5	1.3	1.4	1.3	1.4	1.3	1.3	1.3	1.4	1.6
Boron (B, ppm)	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3
Aluminum (Al, ppm)	662	669	695	648	671	697	711	692	679	773
CEC (meq/ 100g)	11.8	12.4	12.6	11.5	12.1	11.1	11.2	10.8	11	11
K/Mg Ratio	0.09	0.09	0.08	0.09	0.1	0.06	0.05	0.06	0.07	0.08
General Fertility Index (GFI)	53	58	53	54	59	42	40	40	43	44
Percent Base Saturation %K	1.6	1.5	1.4	1.6	1.9	1.6	1.4	1.5	1.9	1.9
%Mg	17.2	16.6	17.1	17.6	18.2	25.7	25.5	25.5	26.6	24.9
%Ca	72	68.8	72.3	70.2	70	72.7	73.1	73	71.6	73.1
%H	8.9	12.8	8.9	10.2	9.6	0	0	0	0	0
%Na	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
pH	7.1	7	7.1	6.8	6.9	7.4	7.5	7.4	7.4	7.5
Buffer pH				6.9	6.9					
EC (ms/cm)	0.22	0.22	0.22	0.3	0.22	0.18	0.17	0.17	0.17	0.17
Saturation %P	4	2	4	3	4	1	1	1	1	1
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	4	4	3	15	4	3	1	2	2	1
Chloride (ppm)	15	9	7	8	10	9	7	8	7	7
Potential Mineralizable Nitrogen (PMN, ppm)	31	32	48	31	35	30	26	28	32	27
Water Extracted Organic C (ppm)	172	168	178	164	174	154	150	158	182	172
Water Extracted Inorganic N (ppm)	6.4	7.4	6.4	15.8	4.6	7.5	8	6.5	7.1	8.5
Water Extracted Organic N (ppm)	63.6	62.6	53.6	64.2	65.4	52.5	72	73.5	52.9	71.5
Solvita CO2-C (ppm)	48	50	103	48	57	44	35	40	50	36
Reactive C (ppm)	740	724	717	774	795	660	605	675	691	623
Soil Health Index	28	30	28	28	31	22	21	21	23	23
%Microbial Active Carbon (MAC)	27.8	29.8	57.8	29.1	32.9	28.3	23.1	25.2	27.5	21.2
Organic C:N ratio	2.7	2.7	3.3	2.6	2.7	2.9	2.1	2.1	3.4	2.4
NRCS Soil Health Calculations	7.1	7.3	12.6	7.1	8.1	6.4	5.7	6.3	7.4	6.1
Biological Soil Quality	4	4	4	4	4	4	3	3	4	3
Estimated Nitrogen Release (ENR, lb/ac/year)	42	42	42	44	43	40	38	39	39	37
Water extracted total N	70	70	60	80	70	60	80	80	60	80
Water extracted Soil Nitrate	3	4	4	14	1	3	3	3	3	3
Water extracted Soil Ammonium	3	3	2	2	4	5	5	4	4	6

Field 16: chemical analysis

	Report # C19231-10101									
Parameters	**16A-1**	**16A-2**	**16A-3**	**16A-4**	**16A-5**	**16B-1**	**16B-2**	**16B-3**	**16B-4**	**16B-5**
Organic Matter (OM, %)	5.9	6	5.9	6	6.2	6.8	6.9	7	6.7	6.5
Phosphorus (Bicarb, ppm)	21	26	19	20	22	27	25	19	22	19
Phosphorus (Bray, ppm)	30	38	36	41	33	53	38	30	32	27
Potassium (K, ppm)	129	127	135	130	140	194	164	185	192	152
Magnesium (Mg, ppm)	436	447	430	472	447	518	485	510	531	496
Calcium (Ca, ppm)	3950	4060	3930	4250	3960	4010	3800	3980	4300	4050
Sodium (Na, ppm)	22	22	20	23	21	24	23	23	25	25
Sulfur (S, ppm)	8	8	8	9	8	11	8	9	9	9
Zinc (Zn, ppm)	4.2	5.2	4.4	5.3	4	4.6	3.9	3.6	3.8	3.4
Manganese (Mn, ppm)	5	5	5	5	6	5	4	8	4	4
Iron (Fe, ppm)	110	108	103	113	114	131	109	135	116	113
Copper (Cu, ppm)	4.8	4.9	4.7	5.1	4.9	5.4	5.2	5.6	5.6	5.2
Boron (B, ppm)	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.8	0.9	0.8
Aluminum (Al, ppm)	864	868	846	908	924	966	896	887	907	880
CEC (meq/ 100g)	25	25.6	24.8	29.4	27.5	28.5	24.7	28.4	27.7	26
K/Mg Ratio	0.09	0.09	0.1	0.08	0.1	0.11	0.1	0.11	0.11	0.09
General Fertility Index (GFI)	63	63	65	70	73	73	64	74	65	62
Percent Base Saturation %K	1.3	1.3	1.4	1.1	1.3	1.7	1.7	1.7	1.8	1.5
%Mg	14.6	14.6	14.4	13.4	13.5	15.1	16.4	15	16	15.9
%Ca	79.1	79.3	79.2	72.3	72	70.3	76.9	70.1	77.7	77.8
%H	4.6	4.5	4.6	12.9	12.9	12.4	4.6	12.8	4.1	4.4
%Na	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
pH	6.9	6.9	6.9	7	7	6.7	6.9	7	6.9	6.9
Buffer pH	6.9	6.9	6.9			6.7	6.9		6.9	6.9
EC (ms/cm)	0.25	0.25	0	0.27	0.25	0.28	0	0	0.27	0.26
Saturation %P	2	3	3	6	5	7	5	4	3	2
Saturation %Al	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	2	2	0	2	2	3	0	0	2	2
Chloride (ppm)	8	9	0	8	8	9	0	0	15	11
Potential Mineralizable Nitrogen (PMN, ppm)	31	29		31	31	35			27	34
Water Extracted Organic C (ppm)	276	238		30	310	352			178	388
Water Extracted Inorganic N (ppm)	6	4.8		6.4	7.1	6.5			14.7	11.2
Water Extracted Organic N (ppm)	4	5.2		13.6	12.9	13.5			15.3	0.8
Solvita CO2-C (ppm)	48	41		48	46	57			38	55
Reactive C (ppm)	844	802		806	828	860			875	801
Soil Health Index	33	33	34	36	38	38	33	39	34	32
%Microbial Active Carbon (MAC)	17.3	17.4		159.3	14.7	16.3			21.4	14
Organic C:N ratio	69	45.8		2.2	24	26.1			11.6	485
NRCS Soil Health Calculations	7.9	7		5.2	8.9	10.6			7.1	9.4
Biological Soil Quality	4	3		4	4	4			3	4
Estimated Nitrogen Release (ENR, lb/ac/year)	72	73	72	73	75	81	82	83	80	78
Water extracted total N	10	10		20	20	20			30	12
Water extracted Soil Nitrate	2	2		2	2	2			7	5
Water extracted Soil Ammonium	4	3		4	5	5			8	6

Field 17: chemical analysis

	Report # C19225-10012									
Parameters	**17A-1**	**17A-2**	**17A-3**	**17A-4**	**17A-5**	**17B-1**	**17B-2**	**17B-3**	**17B-4**	**17B-5**
Organic Matter (OM, %)	4.6	4.4	4.8	4.7	4.7	4.4	4.3	4.1	4.2	4.3
Phosphorus (Bicarb, ppm)	18	14	13	16	15	23	18	19	22	22
Phosphorus (Bray, ppm)	25	23	27	32	31	35	30	27	39	33
Potassium (K, ppm)	123	150	163	149	148	155	153	145	145	163
Magnesium (Mg, ppm)	247	257	245	247	234	231	233	228	219	234
Calcium (Ca, ppm)	2210	2450	2300	2280	2160	2180	2230	2210	2030	2220
Sodium (Na, ppm)	10	10	10	11	9	10	11	11	11	12
Sulfur (S, ppm)	9	15	11	10	9	8	11	8	8	9
Zinc (Zn, ppm)	3.3	3.6	3.4	3.7	3.7	3.1	3.1	2.8	3.4	3.1
Manganese (Mn, ppm)	41	40	42	42	41	24	22	19	21	21
Iron (Fe, ppm)	77	85	83	82	81	93	97	91	96	94
Copper (Cu, ppm)	2.8	3.3	3.1	2.9	2.9	3.1	3.4	3.1	2.9	3.2
Boron (B, ppm)	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3
Aluminum (Al, ppm)	916	972	965	956	918	1019	1052	1036	1060	1061
CEC (meq/ 100g)	15.8	19.6	20	18.7	17.9	16.8	19.5	18.1	17.2	17.1
K/Mg Ratio	0.15	0.18	0.21	0.18	0.19	0.21	0.2	0.19	0.21	0.21
General Fertility Index (GFI)	65	67	72	68	69	77	71	69	75	76
Percent Base Saturation %K	2	2	2.1	2	2.1	2.4	2	2	2.2	2.4
%Mg	13	10.9	10.2	11	10.9	11.4	10	10.5	10.6	11.4
%Ca	69.8	62.5	57.6	61.1	60.2	64.7	57.2	60.9	59.1	64.9
%H	15	24.4	29.9	25.6	26.6	21.2	30.6	26.3	27.8	20.9
%Na	0.3	0.2	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.3
pH	6	6	5.9	6	6	6	6.1	6.2	6	6
Buffer pH	6.8	6.6	6.5	6.6	6.6	6.7	6.5	6.6	6.6	6.7
EC (ms/cm)	0.26	0.26	0.26	0.48	0.4	0.52	0.52	0.45	0.22	0.23
Saturation %P	3	3	4	4	4	4	4	3	5	4
Saturation %Al	0.5	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.6	0.6
Nitrate-N (ppm)	10	5	9	39	29	46	43	36	7	6
Chloride (ppm)	7	8	8	84	64	100	94	88	9	9
Potential Mineralizable Nitrogen (PMN, ppm)	29	29	31	32	34	31	32	26	31	31
Water Extracted Organic C (ppm)	180	230	196	284	152	164	210	188	176	202
Water Extracted Inorganic N (ppm)	17.8	17.5	29.7	17.1	11.1	8.6	10.5	21.3	13.1	9.6
Water Extracted Organic N (ppm)	32.2	42.5	40.3	42.9	38.9	21.4	29.5	48.7	36.9	50.4
Solvita CO2-C (ppm)	41	41	48	50	55	48	50	35	48	48
Reactive C (ppm)	800	794	857	838	822	837	810	762	778	843
Soil Health Index	34	36	38	36	37	41	38	36	40	41
%Microbial Active Carbon (MAC)	23	18	24.4	17.6	35.9	29.1	23.8	18.5	27.1	23.7
Organic C:N ratio	5.6	5.4	4.9	6.6	3.9	7.7	7.1	3.9	4.8	4
NRCS Soil Health Calculations	9.2	10.7	7.1	12.1	7.4	8.6	10.1	5.8	6.9	7.3
Biological Soil Quality	3	3	4	4	4	4	4	3	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	59	56	61	60	60	56	55	53	54	55
Water extracted total N	50	60	70	60	50	30	40	70	50	60
Water extracted Soil Nitrate	12	10	20	8	8	4	3	12	8	4
Water extracted Soil Ammonium	6	8	10	9	3	5	8	9	5	6

Field 19: chemical analysis

	Report # C19225-10012									
Parameters	**19A-1**	**19A-2**	**19A-3**	**19A-4**	**19A-5**	**19B-1**	**19B-2**	**19B-3**	**19B-4**	**19B-5**
Organic Matter (OM, %)	4.1	3.8	3.7	3.8	3.8	3.7	3.7	3.7	3.7	3.7
Phosphorus (Bicarb, ppm)	132	127	128	125	132	121	117	113	115	117
Phosphorus (Bray, ppm)	372	362	368	356	380	335	322	316	336	333
Potassium (K, ppm)	93	99	76	96	94	119	111	104	109	102
Magnesium (Mg, ppm)	560	524	503	517	522	597	579	572	619	571
Calcium (Ca, ppm)	2100	2060	1920	1910	2100	3150	3000	3030	3070	2740
Sodium (Na, ppm)	17	15	14	14	16	12	10	11	12	11
Sulfur (S, ppm)	16	14	13	13	14	12	11	12	12	12
Zinc (Zn, ppm)	5.4	5	6	4.6	7.2	8.7	6.5	7.7	8.4	9.9
Manganese (Mn, ppm)	12	11	11	10	12	18	18	19	18	19
Iron (Fe, ppm)	93	81	82	79	87	72	67	67	67	68
Copper (Cu, ppm)	4.8	4.4	4.3	4.1	4.5	4.4	4.3	4.1	4.3	4.3
Boron (B, ppm)	0.3	0.2	0.2	0.2	0.3	0.5	0.5	0.4	0.6	0.5
Aluminum (Al, ppm)	1476	1461	1418	1364	1489	1392	1311	1290	1254	1258
CEC (meq/ 100g)	16.6	16.1	16.1	15.3	16.3	21	20.1	20.2	20.8	18.7
K/Mg Ratio	0.05	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.05	0.06
General Fertility Index (GFI)	45	46	48	46	46	41	41	41	40	40
Percent Base Saturation %K	1.4	1.6	1.2	1.6	1.5	1.5	1.4	1.3	1.3	1.4
%Mg	28.1	27.1	26	28.1	26.7	23.7	24	23.6	24.8	25.4
%Ca	63.2	63.9	59.7	62.4	64.4	74.9	74.7	75.1	73.9	73.2
%H	6.9	7.1	12.7	7.5	7	0	0	0	0	0
%Na	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.3	0.3
pH	6.7	6.9	7	6.9	6.9	7.7	7.7	7.7	7.5	7.5
Buffer pH	6.9	6.9		6.9	6.9					
EC (ms/cm)	0.22	0.23	0.22	0.21	0.22	0.26	0.25	0.25	0.25	0.24
Saturation %P	32	32	33	34	33	31	32	31	34	34
Saturation %Al	0.3	0.2	0.2	0.2	0.2	0	0	0	0.1	0.1
Nitrate-N (ppm)	1	3	3	2	2	4	4	3	3	3
Chloride (ppm)	14	22	16	22	18	15	12	12	14	18
Potential Mineralizable Nitrogen (PMN, ppm)	35	31	29	28	32	30	28	30	27	27
Water Extracted Organic C (ppm)	230	190	230	176	216	220	224	182	170	144
Water Extracted Inorganic N (ppm)	9.4	10.7	10.9	9.9	7.6	13.2	13.5	14.1	11.5	11.2
Water Extracted Organic N (ppm)	40.6	39.3	39.1	50.1	72.4	46.8	66.5	45.9	48.5	38.8
Solvita CO2-C (ppm)	57	48	41	40	50	44	40	45	38	38
Reactive C (ppm)	846	758	767	741	766	728	704	703	728	753
Soil Health Index	23	24	25	24	24	21	21	21	21	21
%Microbial Active Carbon (MAC)	24.9	25.1	18	22.6	23.2	19.8	17.8	24.9	22.4	26.5
Organic C:N ratio	5.7	4.8	5.9	3.5	3	4.7	3.4	4	3.5	3.7
NRCS Soil Health Calculations	12.1	7.1	10.4	6.2	7.9	7	6.9	6.8	6	5.6
Biological Soil Quality	4	4	3	3	4	4	3	4	3	3
Estimated Nitrogen Release (ENR, lb/ac/year)	53	50	49	50	50	49	49	49	49	49
Water extracted total N	50	50	50	60	80	60	80	60	60	50
Water extracted Soil Nitrate	3	5	4	5	3	7	7	8	7	7
Water extracted Soil Ammonium	6	6	7	5	5	6	7	6	5	4

Field 20: chemical analysis

	Report # C19225-10012									
Parameters	**20A-1**	**20A-2**	**20A-3**	**20A-4**	**20A-5**	**20B-1**	**20B-2**	**20B-3**	**20B-4**	**20B-5**
Organic Matter (OM, %)	3.5	3.4	3.5	3.4	3.5	3	3	2.9	2.9	3
Phosphorus (Bicarb, ppm)	18	14	20	20	14	32	33	33	37	31
Phosphorus (Bray, ppm)	37	29	34	29	27	67	79	68	67	77
Potassium (K, ppm)	114	107	101	121	93	120	136	106	121	131
Magnesium (Mg, ppm)	134	128	132	132	125	94	83	77	83	87
Calcium (Ca, ppm)	1580	1520	1520	1630	1480	650	670	520	530	640
Sodium (Na, ppm)	9	8	8	8	9	13	13	12	13	13
Sulfur (S, ppm)	8	8	8	8	7	12	12	11	12	12
Zinc (Zn, ppm)	4.1	5.6	3.9	5.6	3.8	3.8	12.7	8.6	4.7	6.1
Manganese (Mn, ppm)	104	93	93	96	93	85	81	78	79	82
Iron (Fe, ppm)	71	68	70	66	71	90	93	90	90	93
Copper (Cu, ppm)	1.3	1.2	1.2	1.2	1.1	1.6	1.3	1.1	1.2	1.6
Boron (B, ppm)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Aluminum (Al, ppm)	797	746	788	742	772	1097	1109	1042	1020	1082
CEC (meq/ 100g)	11.7	11.4	12.6	12	11.1	14	15.2	14.4	13.3	15.1
K/Mg Ratio	0.26	0.26	0.24	0.28	0.22	0.39	0.51	0.42	0.44	0.46
General Fertility Index (GFI)	81	81	77	81	78	59	56	54	57	57
Percent Base Saturation %K	2.5	2.4	2.1	2.6	2.1	2.2	2.3	1.9	2.3	2.2
%Mg	9.5	9.4	8.7	9.2	9.4	5.6	4.5	4.5	5.2	4.8
%Ca	67.3	66.9	60.4	68	66.6	23.2	22	18.1	19.9	21.2
%H	20.3	21	28.5	19.9	21.5	68.6	70.8	75.2	72.1	71.4
%Na	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
pH	5.9	6	6	6	6	4.9	4.9	4.9	4.8	4.9
Buffer pH	6.8	6.8	6.7	6.8	6.8	6.2	6.1	6.1	6.2	6.1
EC (ms/cm)	0.26	0.24	0.2	0.29	0.17	0.23	0.24	0.2	0.4	0.32
Saturation %P	6	5	6	5	4	8	9	8	8	9
Saturation %Al	0.7	0.6	0.6	0.6	0.6	3.9	3.6	3.6	4.4	3.5
Nitrate-N (ppm)	14	12	7	18	3	11	12	8	34	23
Chloride (ppm)	7	8	8	16	6	18	8	6	7	6
Potential Mineralizable Nitrogen (PMN, ppm)	33	37	32	31	27	25	25	19	21	23
Water Extracted Organic C (ppm)	130	116	106	110	124	152	110	102	92	62
Water Extracted Inorganic N (ppm)	20.6	18.3	13.5	26.9	17.1	24.2	36.9	23.8	51.3	44.8
Water Extracted Organic N (ppm)	79.4	71.7	66.5	63.1	62.9	25.8	33.1	16.2	48.7	55.2
Solvita CO2-C (ppm)	52	63	50	48	36	33	33	22	26	30
Reactive C (ppm)	733	727	737	715	718	564	532	505	500	507
Soil Health Index	43	43	41	43	42	32	30	29	31	31
%Microbial Active Carbon (MAC)	40.2	54.1	47.2	43.4	29.4	21.8	30.1	21.6	28.7	48.8
Organic C:N ratio	1.6	1.6	1.6	1.7	2	5.9	3.3	6.3	1.9	1.1
NRCS Soil Health Calculations	7.3	8.1	6.7	6.5	5.5	7.4	4.7	4.8	4.1	4.2
Biological Soil Quality	4	4	4	4	3	3	3	3	3	3
Estimated Nitrogen Release (ENR, lb/ac/year)	47	46	47	46	47	42	42	41	41	42
Water extracted total N	100	90	80	90	80	50	70	40	100	100
Water extracted Soil Nitrate	17	14	9	23	11	17	19	13	39	29
Water extracted Soil Ammonium	4	4	5	4	6	7	18	11	12	16

A&L Biologicals

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2020 - Soil Health Analysis of Corn Fields- Final report

Client name	Date
St.Clair Region Soil and Crop Improvement Association 2018-2020 Tier 2 Project	March 9, 2021

The **objective** of this work is to test A&L laboratories' VitTellus soil health analysis and how it corelates to yield and plant performance.

Methods

A&L received 140 corn roots with their respective root ball soil for analysis. The samples were collected by OMAFRA, Ridgetown office from fourteen corn field across South-Western Ontario. Before sample collection, NDVI maps of each field were created and used to select a healthy and a stressed area within each field. Using GPS guided sampling, 5 corn plants were collected per area for a total of 10 plants per field. The roots with their attached soil were code labelled, packaged individually and sent to A&L (Table 1).

Table 1. List of samples received for analysis

Field	Samples	Samples
1	1A-1 to 5	1B-1 to 5
2	2A-1 to 5	2B-1 to 5
3	3A-1 to 5	3B-1 to 5
4	4A-1 to 5	4B-1 to 5
5	5A-1 to 5	5B-1 to 5
6	6A-1 to 5	6B-1 to 5
7	7A-1 to 5	7B-1 to 5
8	8A-1 to 5	8B-1 to 5
9	9A-1 to 5	9B-1 to 5
10	10A-1 to 5	10B-1 to 5
11	11A-1 to 5	11B-1 to 5
12	12A-1 to 5	12B-1 to 5
13	13A-1 to 5	13B-1 to 5
14	14A-1 to 5	14B-1 to 5

Upon receiving the samples, the soil was separated from the roots and sent for the VitTellus soil health analysis. A total of 140 soil samples were analysed. The roots from all 14 fields were washed with tap water, chopped into small pieces, and their DNA was extracted. The DNA was used to compare the root microbial communities of plants from the two areas within each field.

Soil Health Analysis: VitTellus soil health test was used to determine the different chemical parameters of the soil, resulting in a Soil Health Index (SHI). This index ranges from 0 to 60, and the health of the soil is ranked as follow:

- SHI 0 – 20: very low soil health,
- SHI 20 – 30: low soil health,
- SHI 30 – 40: mediocre soil health,
- SHI 40 – 50: good soil health, and
- SHI 50 – 60: very good soil health

The VitTellus soil health test also provides growers with the optimal range for crop productivity of those chemical factors that our research has shown are directly correlated with yield and those microbial activities favourable to plant health.

Analysis of the microbial communities: The root's microbial populations were analysed by Terminal Restriction Fragment Length Polymorphism (TRFLP). TRFLP is a fingerprinting technique for monitoring composition of microbial communities and it can be used to track spatial and temporal shifts in microbial populations. Briefly, a conserved region of DNA extracted from roots (16S rRNA gene for bacteria and ITS gene for fungi) were amplified with fluorescently labeled primers. The fluorescent PCR products were then digested with a restriction enzyme. The size and quantity of the fragments were determined using capillary electrophoresis. The banding pattern obtained provided a fingerprint of the microbial community. The relationship of such fingerprints to one another was identified using a multivariate statistical technique called Principle Component Analysis (PCA). Principle Components (PC) are statistical values generated to best explain the variation in a set of samples. TRFLP data was transformed into binary data (is a specific peak present (1) or not (0)) before performing PCA. PCA analysis clustered the data based on similarity of peak presence; 95% confidence intervals were automatically drawn around each sample group. Groups that do not overlap are consider statistically different in their microbial community.

Yield: Yields were determined by OMAFRA, Ridgetown by hand harvesting the same areas from where the mid season samples were collected. Final yields were kindly provided to us by Anne Verhallen, Soil Management Specialist (Horticultural Crops), Ontario Ministry of Agriculture, Food and Rural Affairs, Ridgetown, Ontario.

Results

Field 1

Site B produced 51 more bu/ac than site A (1A 172.7 bu/ac vs. 1B 224 bu/ac).

A summary of the soil chemical analysis and yield of field 1 is presented in Table 2. The numbers represent the average per area (A or B). Full chemical analysis per sample can be found in the appendix. Occasionally we encountered results that exceeded typical values found within a replicate analysis of a specific group of samples. In such cases the outlier values were discarded. The averages of the results with the outliers however, are presented in the appendix.

Site B had a higher level of organic matter (3.4% vs 1.68% on site A) and reactive carbon (728 ppm vs 500.2 ppm on site A). Reactive Carbon is more complex than the Labile Carbon in that its composed of all the dead and actively decomposing organic matter plus all the living soil microbial community that will eventually die and begin decomposing. Reactive carbon is linked to a number of soil processes, including microbial biomass growth and activity and nutrient cycling. Reactive carbon changes in soils can happen very quickly and a significant decrease in reactive carbon may signal a decline in soil organic matter and indicate the deterioration of physical, chemical, and biological properties and processes related to soil organic matter. The adverse effects caused by the decline in reactive carbon include reduced aggregate stability, increased bulk density, and reduced water infiltration, water-holding capacity, microbial activity, and nutrient availability. Reactive Carbon ranges based on the Cornell Assessment of Soil Health in ppm of Active Carbon for a medium Textured soil are Very Low 0-400, Low 400-500, Medium 500-600, High 600-700 and Very High >700. According to this scale Site A had low levels of reactive carbon while Site B had very high levels of it.

Our previous research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. In this field, both sites studied were below that ideal range (K/Mg: site A = 0.188% and site B = 0.132%). Both sites also had low pH values (site A = pH 5.82 and site B = 5.62).

Site A had a higher GFI and SHI (79 vs 70.6 and 42.2 vs 36.6). Site A also had a slightly higher rate of microbial respiration (45.6 vs 42.4).

The results of the soil health test indicate a better soil health in site A. However, the higher CEC (10.46 vs 5.44) and the higher organic matter (3.4% vs 1.68%) of site B, may have helped the crop on this site during the drought experienced (mid June – July 2020) as organic matter is very much involved in water retention. The higher reactive carbon (728 ppm vs 500.2 ppm) in site B could be also contributing to the higher yield of this site. The higher concentrations of nitrate, Ca, Zn, Mn and S also likely contributed to the higher productivity as site B.

Table 2. Soil Analysis of Field 1.

	Report C20204-10015	
Parameters	**1A**	**1B**
Yield (bu/ac)	172.68	224.01
Organic Matter (OM, %)	1.68	3.4
Phopsphorus (Bicarb, ppm)	55.6	47.8
Phopsphorus (Bray, ppm)	160.4	117.8
Potassium (K, ppm)	71.4	63.6
Magnesium (Mg, ppm)	116.6	148.2
Calcium (Ca, ppm)	560	1136
Sodium (Na, ppm)	10.8	11.4
Sulfur (S, ppm)	5.8	9
Zinc (Zn, ppm)	8.2	17.22
Manganese (Mn, ppm)	21	63.2
Iron (Fe, ppm)	109.2	87.6
Copper (Cu, ppm)	2.52	3.58
Boron (B, ppm)	0.1	0.24
Aluminum (Al, ppm)	718.8	719.6
CEC (meq/ 100g)	5.44	10.46
K/Mg Ratio	0.188	0.132
General Fertility Index (GFI)	79	70.6
Percent Base Saturation %K	3.4	1.56
%Mg	18.1	12.04
%Ca	51.94	55.26
%H	25.72	30.66
%Na	0.88	0.48
pH	5.82	5.62
Buffer pH	6.88	6.72
EC (ms/cm)	0.124	0.19
Saturation %P	28.6	21
Saturation %Al	1.66	1.14
Nitrate-N (ppm)	1.8	5.4
Chloride (ppm)	9.4	14
Potential Mineralizable Nitrogen (PMN, ppm)	30.6	28.8
Water Extracted Organic C (ppm)	25.2	41.6
Water Extracted Inorganic N (ppm)	5.48	6.8
Water Extracted Organic N (ppm)	8.52	7.2
Solvita CO2-C (ppm)	45.6	42.4
Reactive C (ppm)	500.6	728.2
Soil Health Index	42.2	36.6
%Microbial Active Carbon (MAC)	200.32	106.16
Organic C:N ratio	4.08	10.38
NRCS Soil Health Calculations	5.02	4.88
Biological Soil Quality	3.8	3.6
Estimated Nitrogen Release (ENR, lb/ac/year)	61.2	57.6
Water extracted total N	14	14
Water extracted Soil Nitrate	3.2	4.8
Water extracted Soil Ammonium	2.6	2

NRCS soil health calculations based on the Haney test results

Microbial communities

The composition of the bacterial and fungal communities of roots from sites A and B were analysed using TRFLP. We compared the microbial communities from both sites and summarized the results in two different ways: **(A) As vectors:** Figures 1A and 2A show each TRFLP result as a vector (bacterial and fungal, respectively). Each vector represents the community of one plant (named 1- 5). The closer the vectors are to each other, the more similar are the populations they represent. **(B) As single data point:** To visualize if there were any statistically significant differences between the communities from site A and B, we summarized our results as single data points and plotted them two dimensionally (Figures 1B and 2B). The degree of separation between dots indicates the extent of similarities or differences. The further the dots are separated, the greater the difference. The closer they are, the more similar the population. Confidence circles (95%) that do not overlap are considered significantly different.

No differences in the bacterial communities of roots from site A and B were found (Figure 1A and B). All samples clustered together indicating that their bacterial communities were similar.

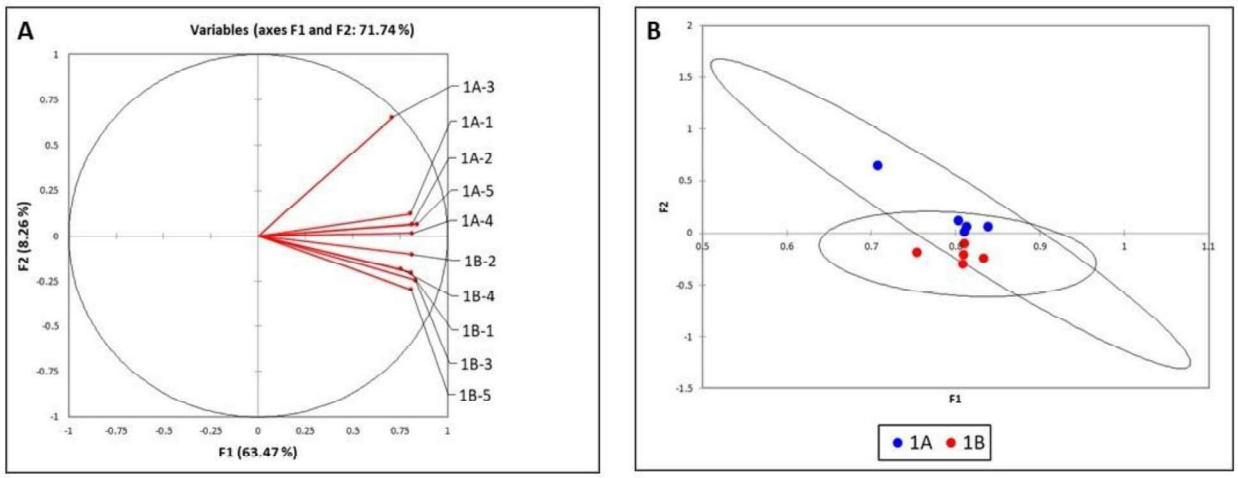

Figure 1. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 1. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

As shown on Figure 2A, the vectors of the fungal communities of the roots from site A were all grouped below the 0 line whereas those from site B were all above. The cluster analysis grouped all the A components close to each other and the B components samples were also closely related (Figure 1B, data as single points). This indicates that the fungal communities from site A and B were different, but the differences were not sufficient as to be highly statistically as indicated by the overlapping confidence circles, Figure 2B). At the same time this is indicative of that some clear differences of the fungal communities exist at the two locations.

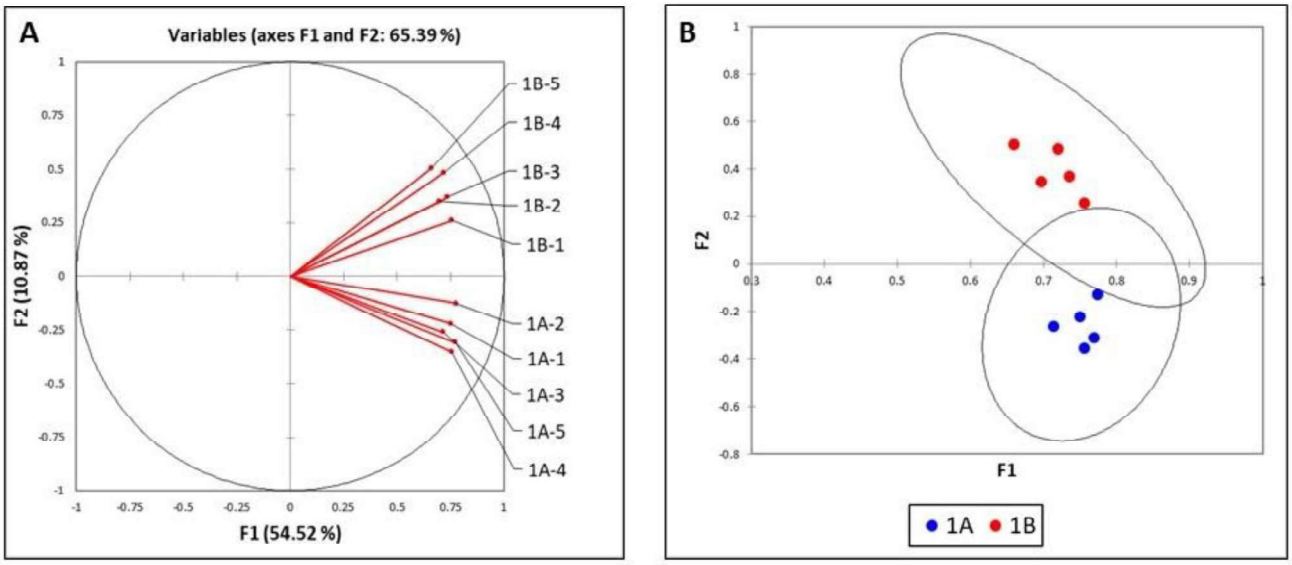

Figure 2. Statistical analysis of TRFLP of the fungal communities in corn roots of field 1. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 2

The productivity of both sites was similarly low. Site A produced 10 bu/ac more than site B (Site A: 141.46 bu/ac vs Site B: 131.76 bu/ac).

A summary of the soil chemical analysis and yield of field 2 is presented in Table 3.

Both sites in this field had very similar soil chemistry. Both sites had relatively high organic matter (4.36), a good GFI (70 and 69.4), moderate SHI (36.6 and 36.4) and ideal biological soil quality (4 and 3.8). Both sites also had high levels of reactive carbon (712.4 and 733.4).

Both sites had slightly acidic soils (pH 5.56 and 5.72) and low K/Mg ratios (0.158 and 0.152).

The slightly higher nitrogen levels of soil A may have given this small yield benefit (total water extracted N 36 vs 22 and 17 vs 4 for water extractable nitrate).

Overall, the chemical profiles of the two soils are remarkably similar.

Table 3. Soil Analysis of Field 2.

	Report C20226-10175	
Parameters	**2A**	**2B**
Yield (bu/ac)	141.46	131.76
Organic Matter (OM, %)	4.36	4.36
Phopsphorus (Bicarb, ppm)	46.4	40
Phopsphorus (Bray, ppm)	107	84.4
Potassium (K, ppm)	136.8	125.2
Magnesium (Mg, ppm)	266	254.2
Calcium (Ca, ppm)	1574	1582
Sodium (Na, ppm)	18.2	18
Sulfur (S, ppm)	13.8	10.6
Zinc (Zn, ppm)	4.56	5.24
Manganese (Mn, ppm)	3.8	3.4
Iron (Fe, ppm)	177.2	181.6
Copper (Cu, ppm)	2.06	1.92
Boron (B, ppm)	0.52	0.6
Aluminum (Al, ppm)	897.4	879.2
CEC (meq/ 100g)	15.54	15.44
K/Mg Ratio	0.158	0.152
General Fertility Index (GFI)	70	69.4
Percent Base Saturation %K	2.28	2.1
%Mg	14.38	13.78
%Ca	43.78	51.46
%H	31.9	32.12
%Na	0.5	0.5
pH	5.56	5.72
Buffer pH	6.58	6.58
EC (ms/cm)	0.272	0.186
Saturation %P	15.4	12.4
Saturation %Al	1.06	0.78
Nitrate-N (ppm)	11.2	1.2
Chloride (ppm)	14	12.6
Potential Mineralizable Nitrogen (PMN, ppm)	37.8	32
Water Extracted Organic C (ppm)	178.8	194.4
Water Extracted Inorganic N (ppm)	19.16	6.94
Water Extracted Organic N (ppm)	16.84	15.06
Solvita CO2-C (ppm)	65.4	50.4
Reactive C (ppm)	712.4	733.4
Soil Health Index	36.6	36.4
%Microbial Active Carbon (MAC)	37.14	26.04
Organic C:N ratio	15.2	13.52
NRCS Soil Health Calculations	9.98	8.46
Biological Soil Quality	4	3.8
Estimated Nitrogen Release (ENR, lb/ac/year)	75.6	64
Water extracted total N	36	22
Water extracted Soil Nitrate	17.2	3.8
Water extracted Soil Ammonium	2	3.2

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial (Figure 3) or the fungal communities (Figure 4) of roots from sites A and B in this field. Our previous research had shown that when the Soil Health Indexes are similar, in this case 36 and 34, and the difference in production is less than 30 bu/ac, no differences in the plant's microbiome can be detected with this technology.

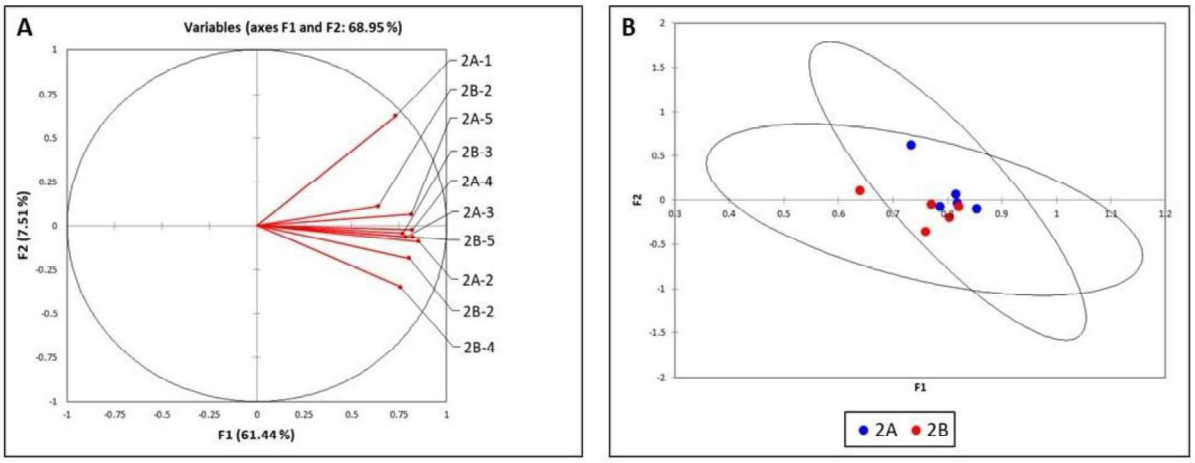

Figure 3. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 2. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

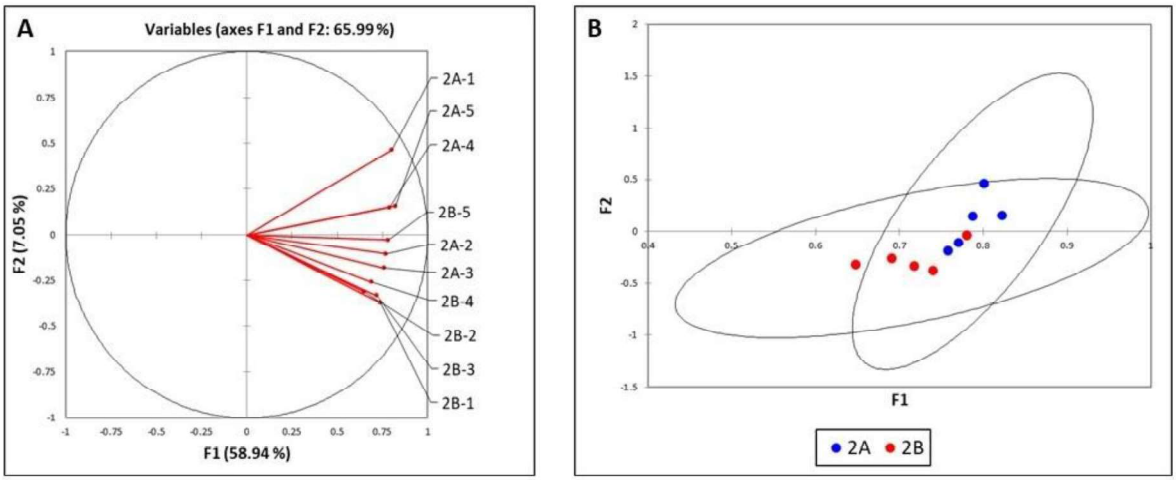

Figure 4. Statistical analysis of TRFLP of the fungal communities in corn roots of field 2. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 3

Site A produced 18.8 bu/ac more than site B (Site A: 227.77 bu/ac vs. Site B: 208.98 bu/ac).

A summary of the soil chemical analysis and yield of field 3 is presented in Table 4.

Some of the samples received for field 3 did not have an adequate amount of soil to complete the full soil health test and some samples are missing values for certain parameters. The data presented in table 4 is representative of the samples that have only the full data reported. A full list of samples and the reported parameters can be found in Appendix 1.

In this field, soil from site A and B had similar levels of organic matter (4% both), phosphorus (36.6 ppm and 34.6 ppm) and percent saturation phosphorus (10.8% and 11.2%). For this soil type, the percent saturation phosphorus is considered high. Both sites also had low pH values (5.9) and K/Mg ratios that were just below the ideal range (0.2).

Site B had 24.6 ppm more potassium (174.8 ppm vs 150.2 ppm) and a higher percent saturation potassium (3.1% vs 2.5%) than site A. Site A had low levels of manganese (7.8 ppm) while site B had very low levels of manganese (3.2 ppm). Site A also had more Zn and a better percentage saturation of calcium than site B (60.2% vs 57.9%).

Site B had a higher GFI (80 and 73.8) and SHI (42.6 and 39). In contrast, site A had considerable higher levels of reactive carbon (922 ppm and 662.7 ppm) and microbial respiration (71.8 and 51.3) than site B. For this soil type, site A had very high levels of reactive carbon and an ideal balance of biological activity and organic matter while site B had high levels of reactive carbon and mediocre biological activity.

Table 4. Soil Analysis of Field 3.

	Report C20212-10122	
Parameters	**3A**	**3B**
Yield (bu/ac)	227.77	208.98
Organic Matter (OM, %)	4.0	4.0
Phopsphorus (Bicarb, ppm)	36.6	34.6
Phopsphorus (Bray, ppm)	73.6	70.6
Potassium (K, ppm)	150.2	174.8
Magnesium (Mg, ppm)	264.0	249.8
Calcium (Ca, ppm)	1834.0	1670.0
Sodium (Na, ppm)	17.2	13.6
Sulfur (S, ppm)	8.2	5.8
Zinc (Zn, ppm)	7.3	4.3
Manganese (Mn, ppm)	7.8	3.2
Iron (Fe, ppm)	97.6	87.4
Copper (Cu, ppm)	2.9	2.4
Boron (B, ppm)	0.4	0.3
Aluminum (Al, ppm)	863.2	839.4
CEC (meq/ 100g)	15.4	14.5
K/Mg Ratio	0.2	0.2
General Fertility Index (GFI)	73.8	80.0
Percent Base Saturation %K	2.5	3.1
%Mg	14.4	14.4
%Ca	60.2	57.9
%H	22.3	24.1
%Na	0.5	0.4
pH	5.9	5.9
Buffer pH	6.7	6.7
EC (ms/cm)	0.2	0.2
Saturation %P	10.8	11.2
Saturation %Al	0.6	0.6
Nitrate-N (ppm)	1.8	1.0
Chloride (ppm)	9.3	9.0
Potential Mineralizable Nitrogen (PMN, ppm)	39.8	35.7
Water Extracted Organic C (ppm)	166.0	183.3
Water Extracted Inorganic N (ppm)	13.1	13.4
Water Extracted Organic N (ppm)	29.4	33.3
Solvita CO2-C (ppm)	71.8	59.3
Reactive C (ppm)	922.0	662.7
Soil Health Index	39.0	42.6
%Microbial Active Carbon (MAC)	43.3	32.4
Organic C:N ratio	5.7	5.6
NRCS Soil Health Calculations	11.0	11.1
Biological Soil Quality	4.0	4.0
Estimated Nitrogen Release (ENR, lb/ac/year)	79.5	71.3
Water extracted total N	42.5	46.7
Water extracted Soil Nitrate	8.3	7.7
Water extracted Soil Ammonium	4.8	6.0

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities (Figure 5) nor on the fungal communities (Figure 6) of roots from sites A and B in this field.

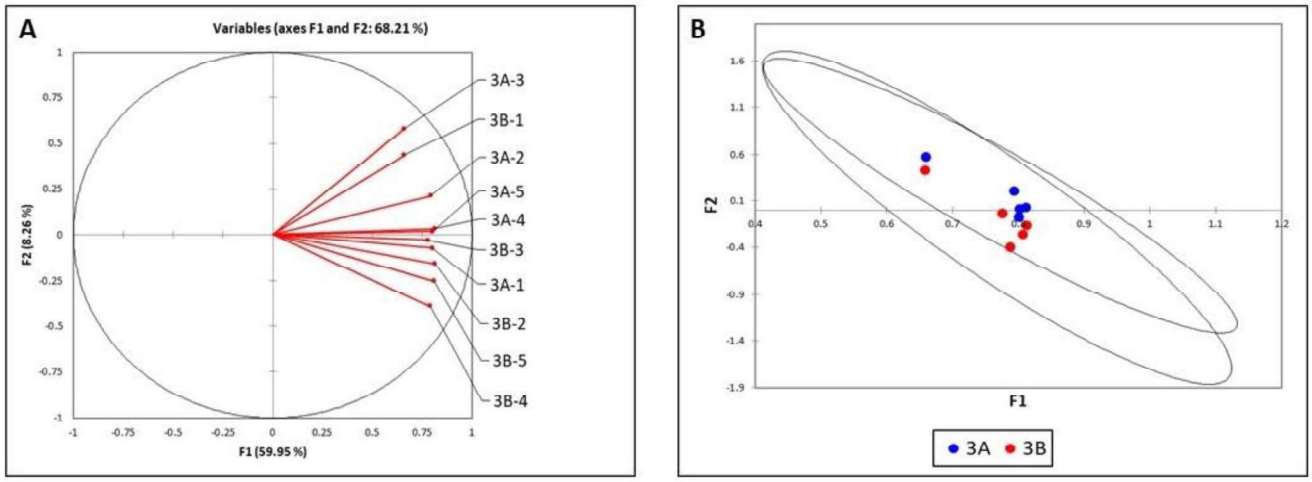

Figure 5. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 3. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

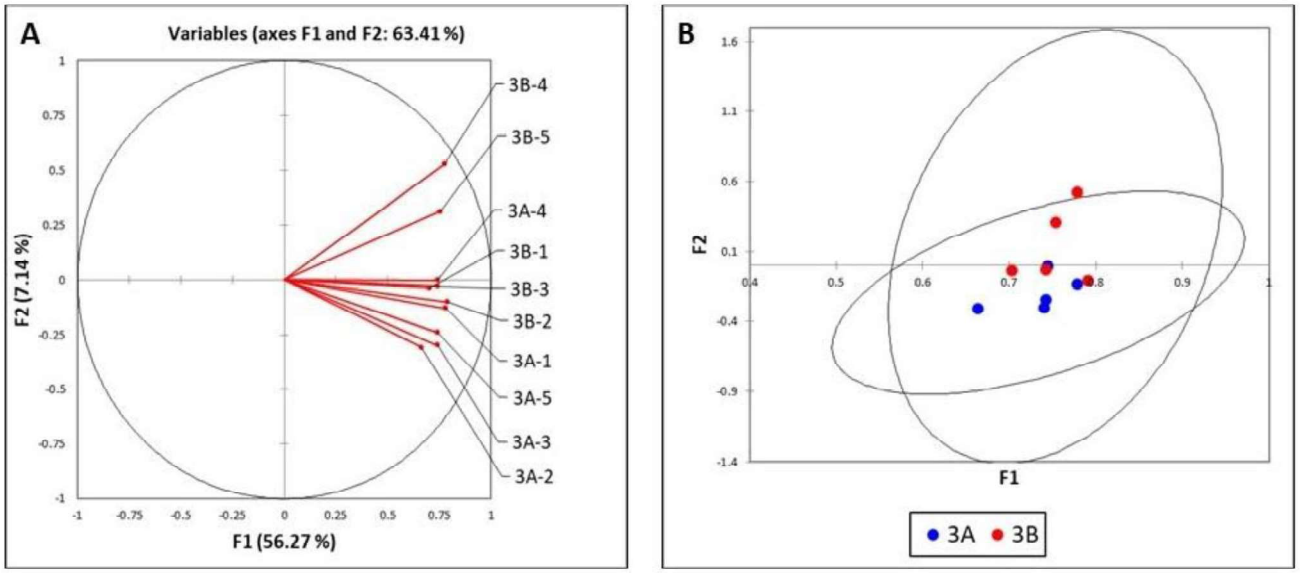

Figure 6. Statistical analysis of TRFLP of the fungal communities in corn roots of field 3. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 4

Site A produced 40.43 bu/ac more than site B (Site A: 230.21bu/ac vs Site B: 189.78 bu/ac).

A summary of the soil chemical analysis and yield of field 4 is presented in Table 5.

In this field, site B had slightly higher phosphorus (71 ppm vs 64.4 ppm) and percent saturation of phosphorus (32 % and 36.2 %) than site A. For both sites, the reported percent saturation of phosphorus is considered high. Site B also had higher potassium (157.2 ppm and 133.2 ppm) and percent saturation of potassium (3.36% and 3.04%) than site A. Both sites were within the optimal range for percent saturation potassium.

Site A had higher GFI (GFI = 70.6 for site A vs GFI = 67.6 for site B) and higher SHI (SHI = 37.4 for site A and SHI = 36.2 for site B) than site B. Both sites also had low K/Mg ratios (0.176 and 0.164).

The % saturation of magnesium of site A was 17.22% while site B had a 20.46%. In general, when the % saturation of magnesium is 20% or higher soils tend to become tight and anaerobic, negatively impacting yield.

The similarities observed in the soil chemistry reports are mirrored in the TRFLP results where no statistically significant differences were observed between the microbial communities (Figures 7 and 8).

Table 5. Soil Analysis of Field 4.

	Report C20204-10015	
Parameters	**4A**	**4B**
Yield (bu/ac)	230.21	189.78
Organic Matter (OM, %)	4.04	4.16
Phopsphorus (Bicarb, ppm)	64.4	71
Phopsphorus (Bray, ppm)	171.4	202.8
Potassium (K, ppm)	133.2	157.2
Magnesium (Mg, ppm)	232	295.6
Calcium (Ca, ppm)	1500	1588
Sodium (Na, ppm)	13.4	15.2
Sulfur (S, ppm)	10	11.8
Zinc (Zn, ppm)	5.76	6.06
Manganese (Mn, ppm)	4.4	5.4
Iron (Fe, ppm)	109.6	124.2
Copper (Cu, ppm)	2.04	1.56
Boron (B, ppm)	0.4	0.36
Aluminum (Al, ppm)	844.8	820.6
CEC (meq/ 100g)	11.26	12.02
K/Mg Ratio	0.176	0.164
General Fertility Index (GFI)	70.6	67.6
Percent Base Saturation %K	3.04	3.36
%Mg	17.22	20.46
%Ca	66.78	65.94
%H	12.42	9.72
%Na	0.5	0.54
pH	6.14	6.66
Buffer pH	6.88	6.9
EC (ms/cm)	0.21	0.226
Saturation %P	26.2	32
Saturation %Al	0.56	0.22
Nitrate-N (ppm)	5.6	6
Chloride (ppm)	15.4	14.2
Potential Mineralizable Nitrogen (PMN, ppm)	38.2	40.8
Water Extracted Organic C (ppm)	99.6	109.2
Water Extracted Inorganic N (ppm)	8.82	10.64
Water Extracted Organic N (ppm)	13.18	23.36
Solvita CO2-C (ppm)	66.6	74.6
Reactive C (ppm)	816.8	847
Soil Health Index	37.4	36.2
%Microbial Active Carbon (MAC)	70.16	72.4
Organic C:N ratio	12.1	5.34
NRCS Soil Health Calculations	8.54	9.48
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	76.4	81.6
Water extracted total N	22	34
Water extracted Soil Nitrate	6.2	6.6
Water extracted Soil Ammonium	2.8	4

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found on the bacterial populations of roots from site A and B (Figure 7B). In contrast, the fungal communities from sites A and B clearly separated (Figure 8A), highlighting the differences between them. While the differences were not statistically significant as indicated by the touching confidence circles there is a clear trend of differences in the fungal populations (Figure 8B).

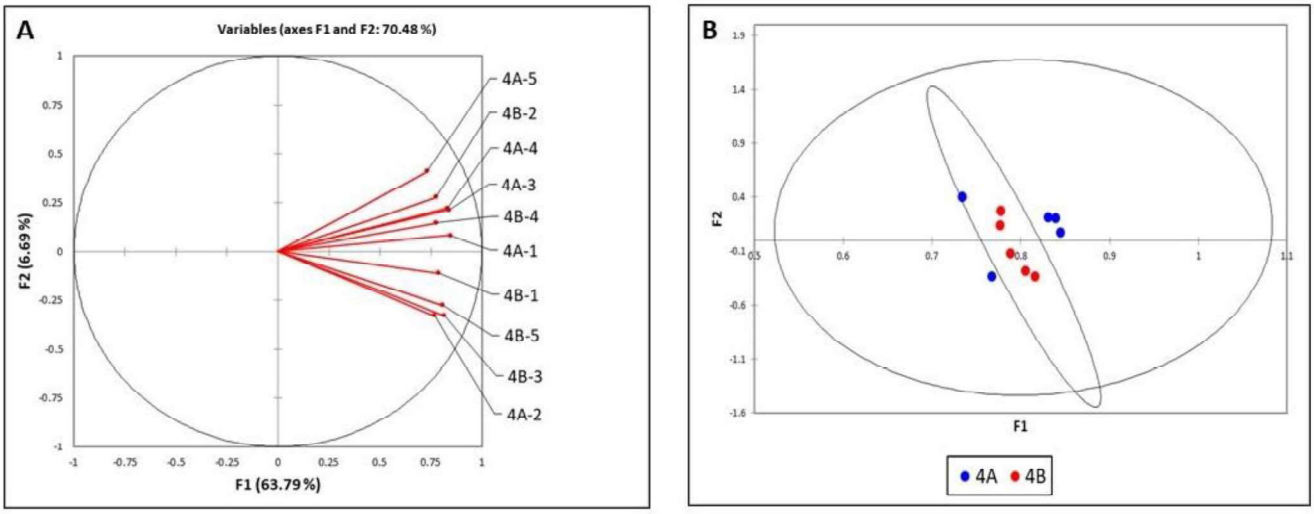

Figure 7. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 4. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

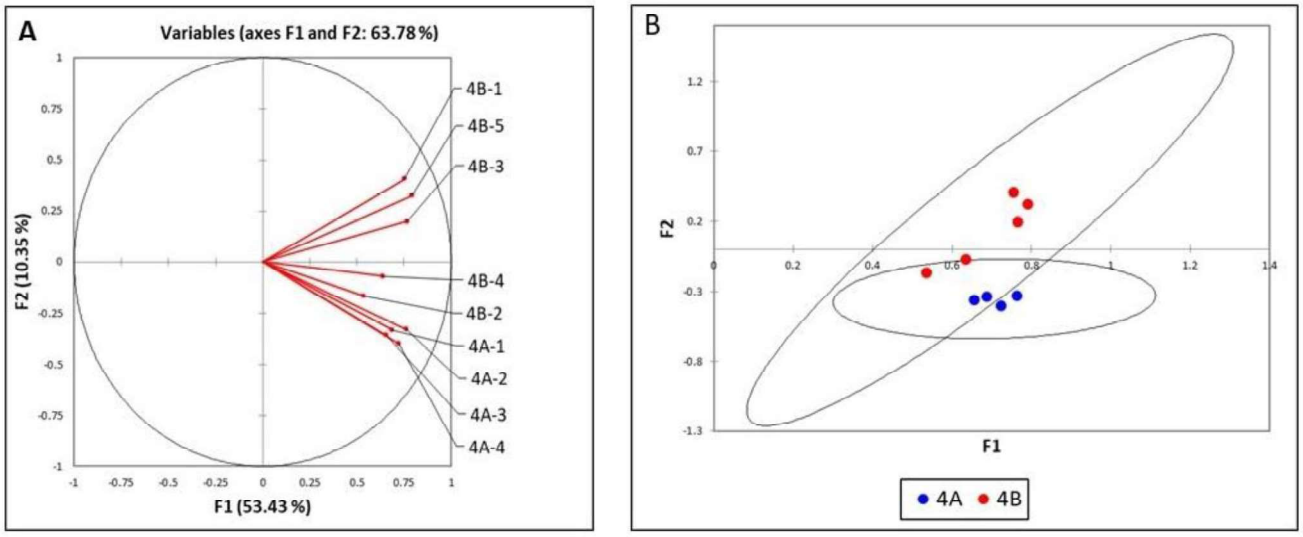

Figure 8. Statistical analysis of TRFLP of the fungal communities in corn roots of field 4. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 5

Site B produced 20.83 bu/ac more than site B (Site B: 196.95 bu/ac vs. 176.12 bu/ac).

A summary of the soil chemical analysis and yield of field 5 is presented in Table 6.

In this field, site A had slightly higher phosphorus (29.4 ppm vs 21.2 ppm) and site B had slightly higher percent saturation of phosphorus (7.4 % and 4 %). For both sites, the reported percent saturation of phosphorus is considered low. Site B also had higher potassium (157.2 ppm and 133.2 ppm) and percent saturation of potassium (3.36% and 3.04%). Both sites were below the optimal range for percent saturation potassium.

Both sites had similar GFI (55.8 and 58) and SHI (29.4 and 30.6), the GFI and SHI were low in this field. Both sites also had low K/Mg ratios (0.134 and 0.11). Site B had higher levels of reactive carbon (724 vs 662 ppm), higher soil respiration (66.6 vs 48.8 ppm) and higher percentage of microbial active carbon (106.74 vs 74.78) than site A.

The similarities observed in the soil chemistry reports are mirrored in the TRFLP results where no differences were observed between the microbial communities (Figures 9 and 10).

Table 6. Soil Analysis of Field 5.

	Report C20204-10015	
Parameters	**5A**	**5B**
Yield (bu/ac)	176.12	196.95
Organic Matter (OM, %)	2.48	2.68
Phopsphorus (Bicarb, ppm)	29.4	21.2
Phopsphorus (Bray, ppm)	48	36
Potassium (K, ppm)	86	76.8
Magnesium (Mg, ppm)	199.4	212.4
Calcium (Ca, ppm)	1698	1328
Sodium (Na, ppm)	14.2	13.6
Sulfur (S, ppm)	8	7.2
Zinc (Zn, ppm)	3.22	4.22
Manganese (Mn, ppm)	26.4	25
Iron (Fe, ppm)	64.4	64
Copper (Cu, ppm)	0.9	0.96
Boron (B, ppm)	0.42	0.36
Aluminum (Al, ppm)	659.2	627.2
CEC (meq/ 100g)	10.42	9.48
K/Mg Ratio	0.134	0.11
General Fertility Index (GFI)	55.8	58
Percent Base Saturation %K	2.12	2.1
%Mg	15.98	18.62
%Ca	81.56	70.08
%H	0	8.56
%Na	0.6	0.64
pH	7.72	7.08
Buffer pH		6.9
EC (ms/cm)	0.186	0.162
Saturation %P	4	7.4
Saturation %Al	0.02	0.1
Nitrate-N (ppm)	3.4	3
Chloride (ppm)	11.8	11.2
Potential Mineralizable Nitrogen (PMN, ppm)	31.8	38.2
Water Extracted Organic C (ppm)	68.4	62.8
Water Extracted Inorganic N (ppm)	6.78	8.52
Water Extracted Organic N (ppm)	5.22	21.48
Solvita CO2-C (ppm)	48.8	66.6
Reactive C (ppm)	662	724
Soil Health Index	29.4	30.6
%Microbial Active Carbon (MAC)	74.48	106.74
Organic C:N ratio	18.32	3.36
NRCS Soil Health Calculations	5.86	7.7
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	63.6	76.4
Water extracted total N	18	30
Water extracted Soil Nitrate	3.6	5.2
Water extracted Soil Ammonium	3.2	3.6

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial and fungal communities of roots from sites A and B tend to separate, indicating that they were somehow different (Figure 9A and 10A). However, the differences were not statistically significant but the trend was clearly evident (Figure 9B and 10B).

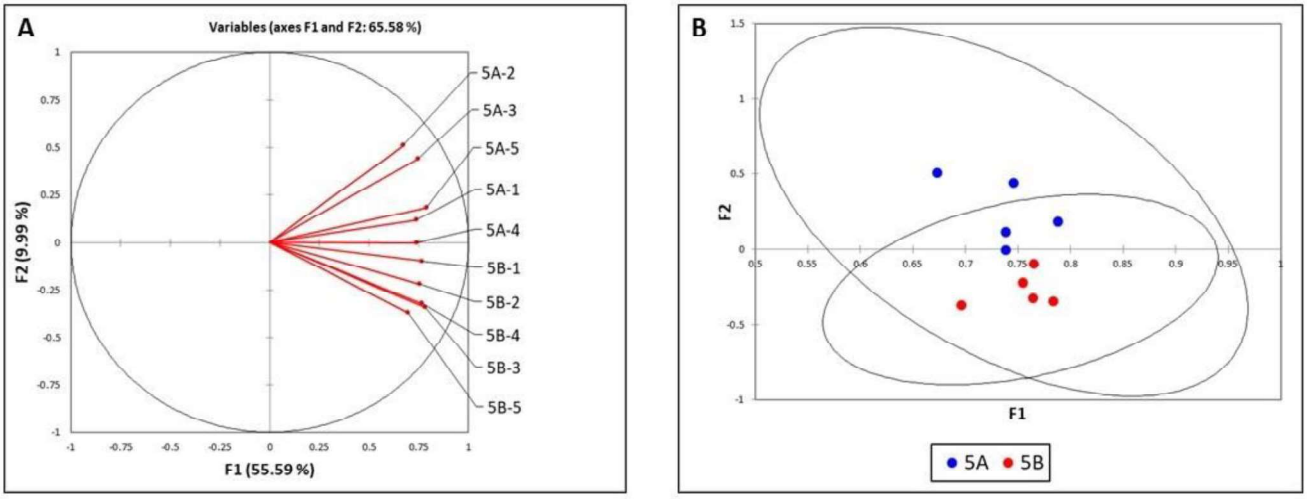

Figure 9. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 5. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

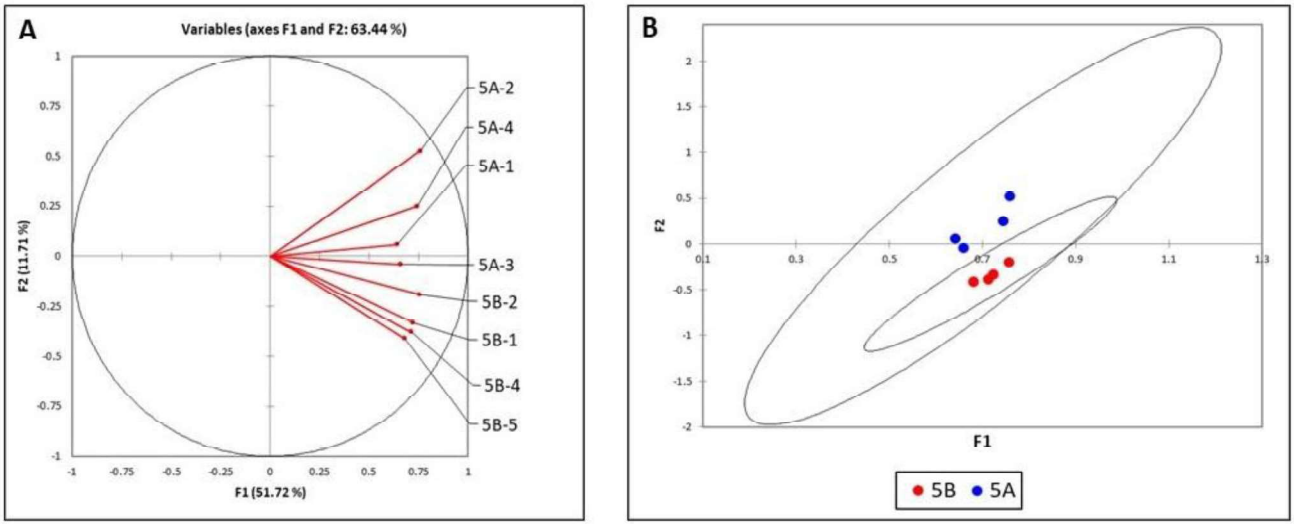

Figure 10. Statistical analysis of TRFLP of the fungal communities in corn roots of field 5. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 6

Site A produced 49.19 bu/ac more than site B (site A: 229.53 bu/ac vs. 180.34 bu/ac).

A summary of the soil chemical analysis and yield of field 6 is presented in Table 7.

In this field, site A had slightly higher phosphorus (31.2 ppm vs 23.4 ppm) and percent saturation of phosphorus (8.2 % and 6.8 %) than site B. For both sites, the reported percent saturation of phosphorus is considered low. Site B had higher potassium (131.8 ppm and 126.8 ppm) and both sites had similar percent saturation of potassium (4.06% and 3.3%). Both sites were within the optimal range for percent saturation potassium.

The K/Mg ratio on site A (0.196) is considered medium, while the K/Mg ratio in site B (0.14) is considered low.

Site A had a higher GFI (73.8 and 64), SHI (37.8 and 34.2). Both sites have a good GFI, and moderate SHI.

The high % saturation of magnesium explain the difference in production. Site A had a % Mg of 20.72 whereas site B had a % Mg of 23.8 (Table 7), 23.8% is above the recommended range and at that % of Mg soils become anaerobic negatively impacting production.

The similarities observed in the soil chemistry reports are mirrored in the TRFLP results where no differences were observed between the microbial communities.

Most obvious was the difference in the total water extractable amount of nitrogen (82 vs 33), the water extractable soil nitrate (47.4 vs 18) and the water extractable ammonium (23.4 vs 7.4). The differences in available nitrogen likely has an impact on the yield effects.

Table 7. Soil Analysis of Field 6.

	Report C20204-10015	
Parameters	**6A**	**6B**
Yield (bu/ac)	229.53	180.34
Organic Matter (OM, %)	2.96	2.78
Phopsphorus (Bicarb, ppm)	31.2	23.4
Phopsphorus (Bray, ppm)	56.2	36.2
Potassium (K, ppm)	126.8	131.8
Magnesium (Mg, ppm)	199.4	291
Calcium (Ca, ppm)	958	1240
Sodium (Na, ppm)	11.8	12.2
Sulfur (S, ppm)	13.8	8.6
Zinc (Zn, ppm)	2.3	2.74
Manganese (Mn, ppm)	13.2	19
Iron (Fe, ppm)	70.4	82.2
Copper (Cu, ppm)	0.54	0.84
Boron (B, ppm)	0.22	0.22
Aluminum (Al, ppm)	879.8	677
CEC (meq/ 100g)	8	10.18
K/Mg Ratio	0.196	0.14
General Fertility Index (GFI)	73.8	64
Percent Base Saturation %K	4.06	3.3
%Mg	20.72	23.8
%Ca	59.82	60.9
%H	14.74	11.5
%Na	0.66	0.54
pH	6.06	6.42
Buffer pH	6.9	6.9
EC (ms/cm)	0.536	0.3
Saturation %P	8.2	6.8
Saturation %Al	0.94	0.32
Nitrate-N (ppm)	49.2	20
Chloride (ppm)	12.2	16
Potential Mineralizable Nitrogen (PMN, ppm)	36.2	41.6
Water Extracted Organic C (ppm)	41.6	68.8
Water Extracted Inorganic N (ppm)	70.56	25.26
Water Extracted Organic N (ppm)	11.44	10.175
Solvita CO2-C (ppm)	60.8	83.2
Reactive C (ppm)	714.8	691.6
Soil Health Index	37.8	34.2
%Microbial Active Carbon (MAC)	162.62	119.54
Organic C:N ratio	50.72	17.3
NRCS Soil Health Calculations	17.74	9.24
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	72.4	83.2
Water extracted total N	82	33
Water extracted Soil Nitrate	47.4	18
Water extracted Soil Ammonium	23.4	7.4

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities (Figure 11) nor on the fungal communities (Figure 12) of roots from sites A and B in this field.

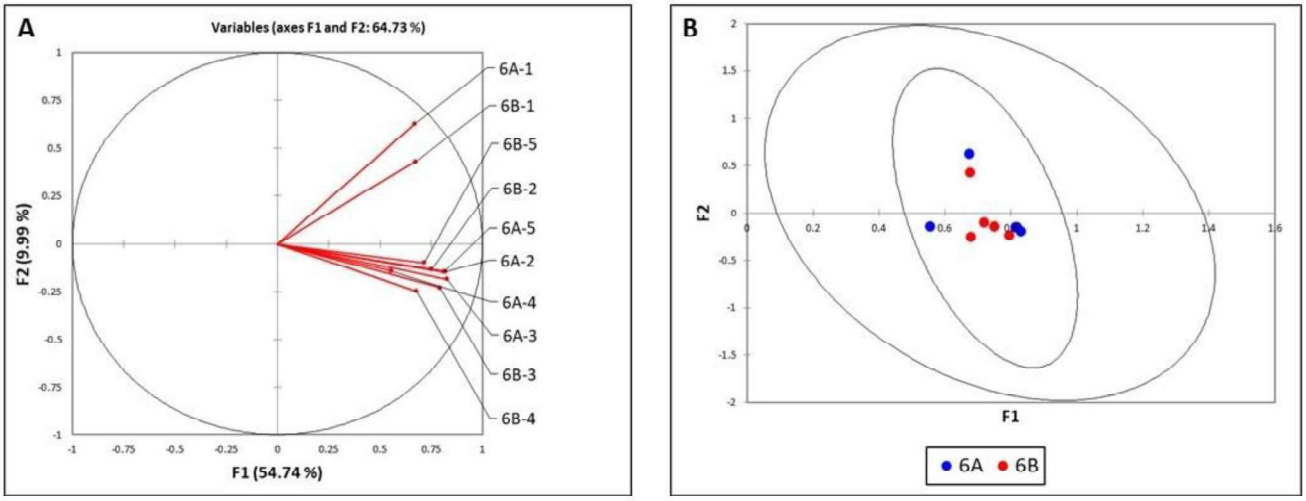

Figure 11. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 6. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

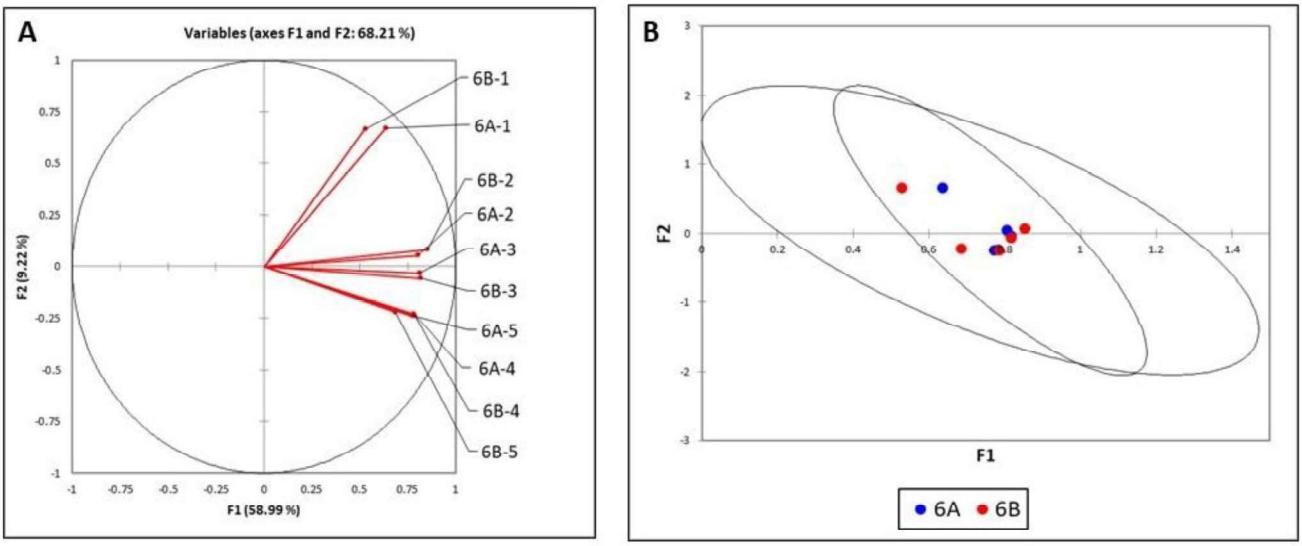

Figure 12. Statistical analysis of TRFLP of the fungal communities in corn roots of field 6. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 7

Site A and B had the same productivity (Site A: 216.19 bu/ac and Site B: 213.19 bu/ac).

A summary of the soil chemical analysis and yield of field 7 is presented in Table 8.

The soils from both sites in field 7 have similar soil chemistry with close to ideal values for many of the key parameters.

Site A and B had ideal values for K/Mg ratio (0.23 and 0.25) and percent saturation potassium (3.66% and 2.72%). Both sites had high GFIs (77.8 and 78.8) and good SHIs (42 and 42.6).

Site A had higher reactive carbon (791.2ppm and 646.2 ppm) and higher microbial respiration (89.2 and 50.8).

The productivity of this field could be improved by addressing the low pH levels (Site A: 5.92, Site B: 5.18).

Overall, the two sites were remarkably similar in their chemical fertility components. While site A had higher levels of K that site B (172 vs 126) site B had higher levels of P than site A (170 vs 124).

Table 8. Soil Analysis of Field 7.

	Report C20204-10015	
Parameters	**7A**	**7B**
Yield (bu/ac)	216.19	213.19
Organic Matter (OM, %)	4.02	3.38
Phopsphorus (Bicarb, ppm)	52.8	59.6
Phopsphorus (Bray, ppm)	126.4	170.4
Potassium (K, ppm)	171.8	126.2
Magnesium (Mg, ppm)	232	156
Calcium (Ca, ppm)	1686	1246
Sodium (Na, ppm)	12.2	14.8
Sulfur (S, ppm)	9.4	13.8
Zinc (Zn, ppm)	5.16	6.74
Manganese (Mn, ppm)	26.2	28.4
Iron (Fe, ppm)	80.6	81.8
Copper (Cu, ppm)	4.54	7.12
Boron (B, ppm)	0.32	0.2
Aluminum (Al, ppm)	778.6	929.8
CEC (meq/ 100g)	12.02	11.98
K/Mg Ratio	0.23	0.248
General Fertility Index (GFI)	77.8	78.8
Percent Base Saturation %K	3.66	2.72
%Mg	14.22	10.9
%Ca	70.12	52.32
%H	9.76	33.5
%Na	0.44	0.56
pH	5.92	5.18
Buffer pH	6.9	6.66
EC (ms/cm)	0.35	0.3
Saturation %P	20.8	23.6
Saturation %Al	0.72	2.52
Nitrate-N (ppm)	24.2	16.2
Chloride (ppm)	16.6	19.2
Potential Mineralizable Nitrogen (PMN, ppm)	44.2	33.6
Water Extracted Organic C (ppm)	86	127.2
Water Extracted Inorganic N (ppm)	25.98	22.62
Water Extracted Organic N (ppm)	12.02	29.38
Solvita CO2-C (ppm)	89.2	50.8
Reactive C (ppm)	791.2	646.2
Soil Health Index	42	42.6
%Microbial Active Carbon (MAC)	103.54	41.88
Organic C:N ratio	8.2	4.76
NRCS Soil Health Calculations	10.7	8.08
Biological Soil Quality	4.2	4
Estimated Nitrogen Release (ENR, lb/ac/year)	88.4	67.2
Water extracted total N	38	52
Water extracted Soil Nitrate	22.2	17.6
Water extracted Soil Ammonium	3.8	5

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site A were similar to each other, as evident from the clustering of the samples on the top right quadrant of the graph (Figure 13 A). The root's bacterial populations from site B were also similar to each other, as indicated by the clustering of the samples on the bottom right quadrant of the graph (Figure 13A). Although the bacterial communities from sites A and B were somehow different (grouped into clusters), the differences were not statistically significant (Figure 13B). A similar pattern was observed in the case of the fungal communities Figure 14. The trends do indicate that there were different communities and fungi acting in the soils at the two sites.

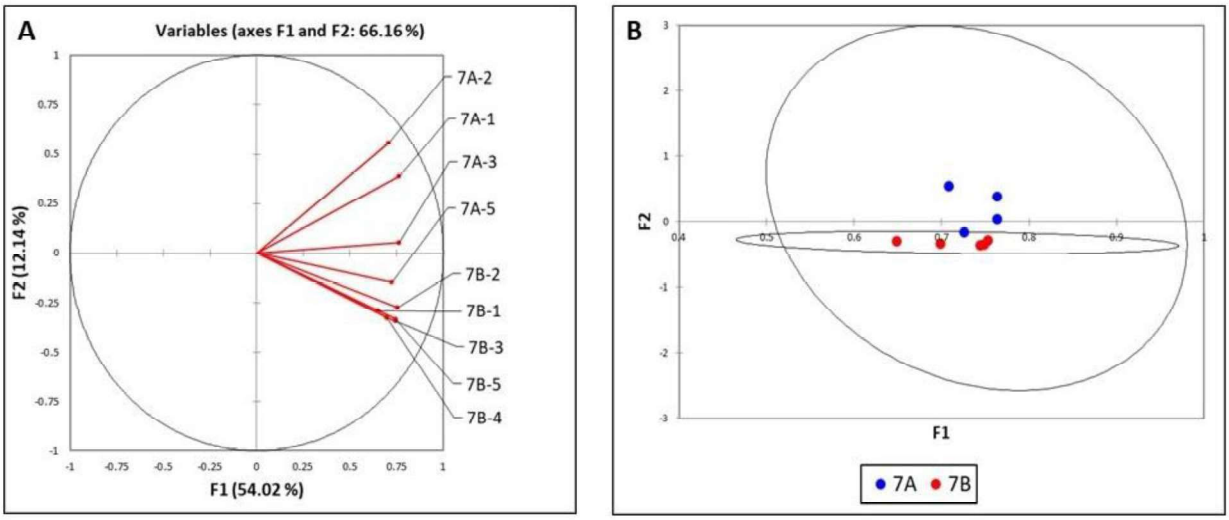

Figure 13. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 7. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

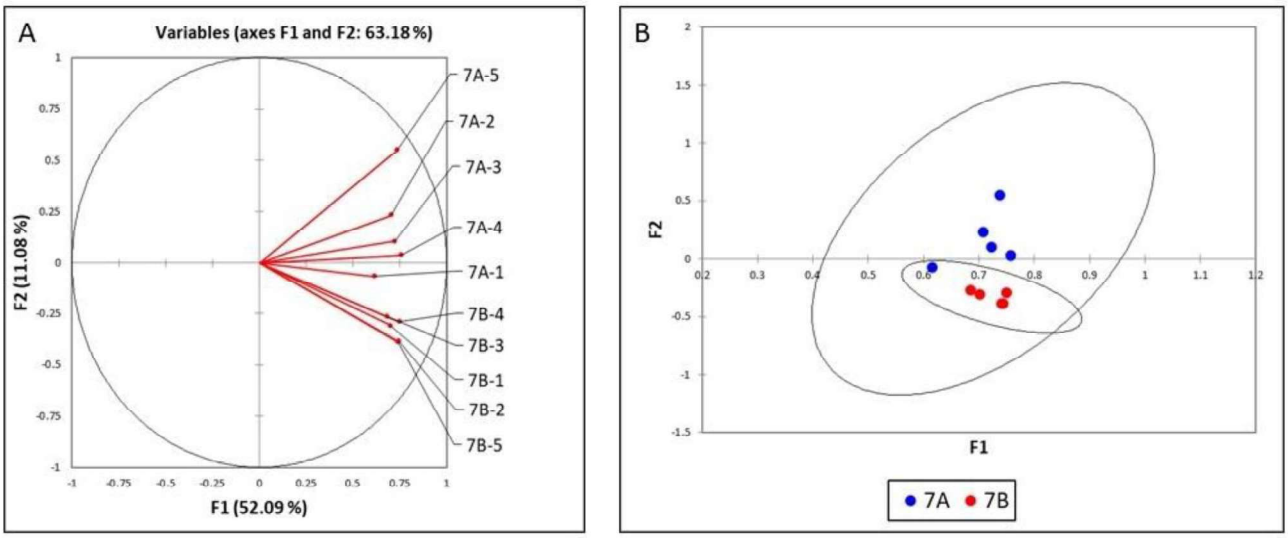

Figure 14. Statistical analysis of TRFLP of the fungal communities in corn roots of field 7. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 8

Site A produced 55.41 bu/ac more than site B (Site A: 251.72 bu/ac vs. 196.31 bu/ac).

A summary of the soil chemical analysis and yield of field 8 is presented in Table 9. Some of the samples received for field 8 did not have an adequate amount of soil to complete the full soil health test and some samples are missing values for certain parameters. The data presented in table 4 is representative of the samples that all the values measured. A full list of samples and the reported parameters can be found in Appendix 1.

In this field site A had a higher organic matter content (7% vs. 3.4%), potassium (164.4 ppm vs. 95.4 ppm) and percent saturation potassium (2.2% vs. 1.2%). For this soil type, the percent saturation of potassium in site A falls within the ideal range while site B is below the ideal range. Site A also had a higher percent saturation of phosphorus (7.2 % vs 4%). For this soil type, site A had a good level of phosphorus while site B had mediocre levels. Both sites K/Mg ratios that were well below the ideal range (0.1 and 0.1) and site A had an acidic pH (site A pH = 5.8 vs. site B pH = 7.8).

Site A had a mediocre GFI (63.2) and SHI (33.4) while the GFI and SHI of site B were considered low (GFI = 50.4, SHI = 26).

The high values for microbial respiration and reactive carbon in site A (104.3ppm and 845.5 ppm respectively) are inline with the high organic matter reported.

The yield results support differences observed in the soil chemistry and microbial communities present in each site.

Table 9. Soil Analysis of Field 8.

	Report C20212-10122	
Parameters	**8A**	**8B**
Yield (bu/ac)	251.72	196.31
Organic Matter (OM, %)	7.0	3.4
Phopsphorus (Bicarb, ppm)	25.2	28.0
Phopsphorus (Bray, ppm)	49.4	50.6
Potassium (K, ppm)	164.4	95.4
Magnesium (Mg, ppm)	449.4	451.6
Calcium (Ca, ppm)	2068.0	3264.0
Sodium (Na, ppm)	16.0	22.4
Sulfur (S, ppm)	10.4	9.8
Zinc (Zn, ppm)	7.1	4.6
Manganese (Mn, ppm)	4.0	30.2
Iron (Fe, ppm)	91.4	61.0
Copper (Cu, ppm)	2.2	1.4
Boron (B, ppm)	0.4	0.6
Aluminum (Al, ppm)	855.8	588.2
CEC (meq/ 100g)	19.3	20.4
K/Mg Ratio	0.1	0.1
General Fertility Index (GFI)	63.2	50.4
Percent Base Saturation %K	2.2	1.2
%Mg	19.6	18.5
%Ca	54.1	80.0
%H	23.7	0.0
%Na	0.4	0.5
pH	5.8	7.8
Buffer pH	6.6	0.0
EC (ms/cm)	0.2	0.2
Saturation %P	7.2	4.0
Saturation %Al	0.5	0.0
Nitrate-N (ppm)	5.3	1.6
Chloride (ppm)	11.7	13.6
Potential Mineralizable Nitrogen (PMN, ppm)	48.3	37.4
Water Extracted Organic C (ppm)	210.7	121.2
Water Extracted Inorganic N (ppm)	17.9	9.9
Water Extracted Organic N (ppm)	28.8	20.1
Solvita CO2-C (ppm)	104.3	64.4
Reactive C (ppm)	845.5	718.0
Soil Health Index	33.4	26.0
%Microbial Active Carbon (MAC)	50.0	53.6
Organic C:N ratio	7.7	7.7
NRCS Soil Health Calculations	15.4	8.6
Biological Soil Quality	4.3	4.0
Estimated Nitrogen Release (ENR, lb/ac/year)	96.7	74.8
Water extracted total N	46.7	30.0
Water extracted Soil Nitrate	12.3	6.8
Water extracted Soil Ammonium	5.7	3.2

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site A were similar to each other, as evident from the clustering of the samples on the bottom right quadrant of the graph (Figure 15 A). The root's bacterial populations from site B were also similar to each other, as indicated by the clustering of the samples on the top right quadrant of the graph (Figure 15A). Although the bacterial communities from sites A and B were somehow different (grouped into clusters), the differences were not statistically significant (Figure 15B). A similar pattern was observed in the case of the fungal communities (Figure 16). There is a clear trend of differences in the microbial communities in the soils at the two sites.

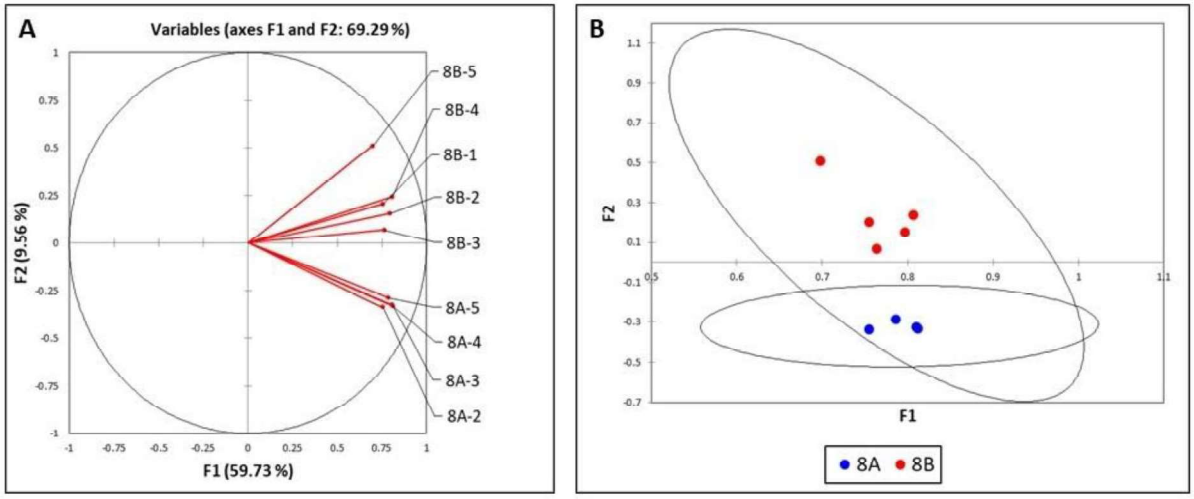

Figure 15. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 8. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

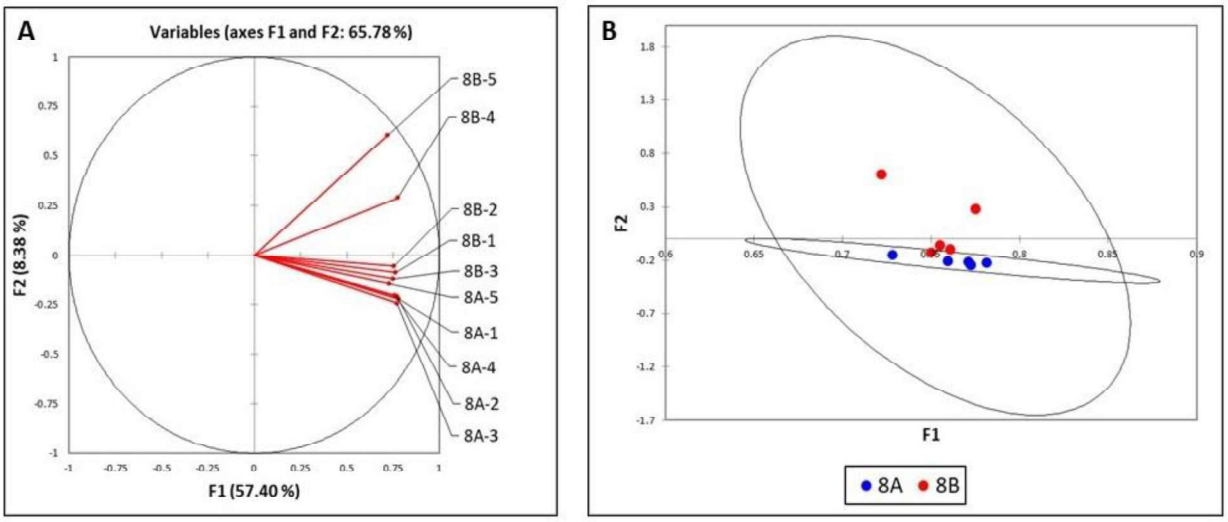

Figure 16. Statistical analysis of TRFLP of the fungal communities in corn roots of field 8. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 9

Similar yields were reported for site A and B (Site A 176.04 bu/ac vs. 183.57 bu/ac).

A summary of the soil chemical analysis and yield of field 9 is presented in Table 10. Some of the samples received for field 9 did not have an adequate amount of soil to complete the full soil health test and some samples are missing values for certain parameters. The data presented in table 4 is representative of the samples that had reported values only. A full list of samples and the reported parameters can be found in Appendix 1.

The similarities observed in the soil chemistry were reflected in the yield data. In this field site B had higher phosphorus (53.4 ppm vs 45.6 ppm), percent saturation phosphorus (18.2% vs 7.2%), potassium (149.9 ppm vs 134.8 ppm) and percent saturation potassium (2.26% vs 1.82%). For this soil type the percent saturation phosphorus in site B is considered high and site A is considered good. The percent saturation of potassium was within the ideal range for site B but was low in site A.

Both sites had similar GFI (66 and 67.8) and SHI (35.4 and 35.75). The GFI values were considered good and the SHI values were considered mediocre.

Soil B had very significantly higher levels of nitrogenous compounds both as potential release (46.5 vs 75), and as water extractable total N (37.5 vs 87.5) and nitrate ions (10.3 vs 54).

No differences were found in the bacterial communities (Figure 17) nor on the fungal communities (Figure 18) of roots from sites A and B in this field.

Table 10. Soil Analysis of Field 9.

	Report C20212-10122	
Parameters	**9A**	**9B**
Yield bu/ac	176.04	183.57
Organic Matter (OM, %)	3.40	4.30
Phopsphorus (Bicarb, ppm)	45.60	53.40
Phopsphorus (Bray, ppm)	97.80	132.80
Potassium (K, ppm)	134.80	149.40
Magnesium (Mg, ppm)	200.00	264.40
Calcium (Ca, ppm)	3404.00	2139.60
Sodium (Na, ppm)	15.60	18.40
Sulfur (S, ppm)	7.20	7.00
Zinc (Zn, ppm)	12.32	15.50
Manganese (Mn, ppm)	117.80	71.80
Iron (Fe, ppm)	78.60	103.80
Copper (Cu, ppm)	3.86	5.14
Boron (B, ppm)	0.48	0.48
Aluminum (Al, ppm)	626.00	727.20
CEC (meq/ 100g)	19.08	17.08
K/Mg Ratio	0.21	0.17
General Fertility Index (GFI)	66.00	67.80
Percent Base Saturation %K	1.82	2.26
%Mg	8.74	12.94
%Ca	89.24	76.30
%H	0.00	8.04
%Na	0.36	0.48
pH	8.00	7.00
Buffer pH		6.90
EC (ms/cm)	0.19	0.43
Saturation %P	7.20	18.20
Saturation %Al	0.00	0.10
Nitrate-N (ppm)	4.00	47.50
Chloride (ppm)	8.25	8.50
Potential Mineralizable Nitrogen (PMN, ppm)	23.25	37.50
Water Extracted Organic C (ppm)	96.50	88.00
Water Extracted Inorganic N (ppm)	14.05	58.48
Water Extracted Organic N (ppm)	23.45	29.03
Solvita CO2-C (ppm)	30.50	64.50
Reactive C (ppm)	703.50	848.67
Soil Health Index	35.40	35.75
%Microbial Active Carbon (MAC)	31.25	73.18
Organic C:N ratio	4.25	3.15
NRCS Soil Health Calculations	4.65	7.63
Biological Soil Quality	3.25	4.00
Estimated Nitrogen Release (ENR, lb/ac/year)	46.50	75.00
Water extracted total N	37.50	87.50
Water extracted Soil Nitrate	10.25	53.75
Water extracted Soil Ammonium	3.75	4.50

NRCS soil health calculations based on the Haney test results.

Microbial communities

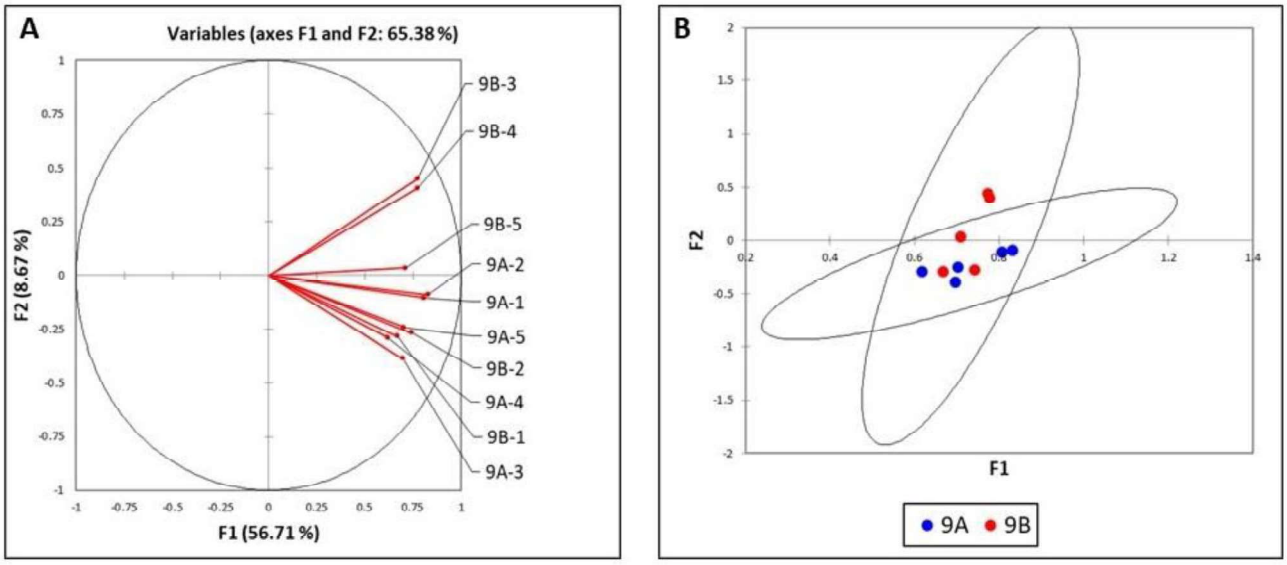

Figure 17. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 9. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

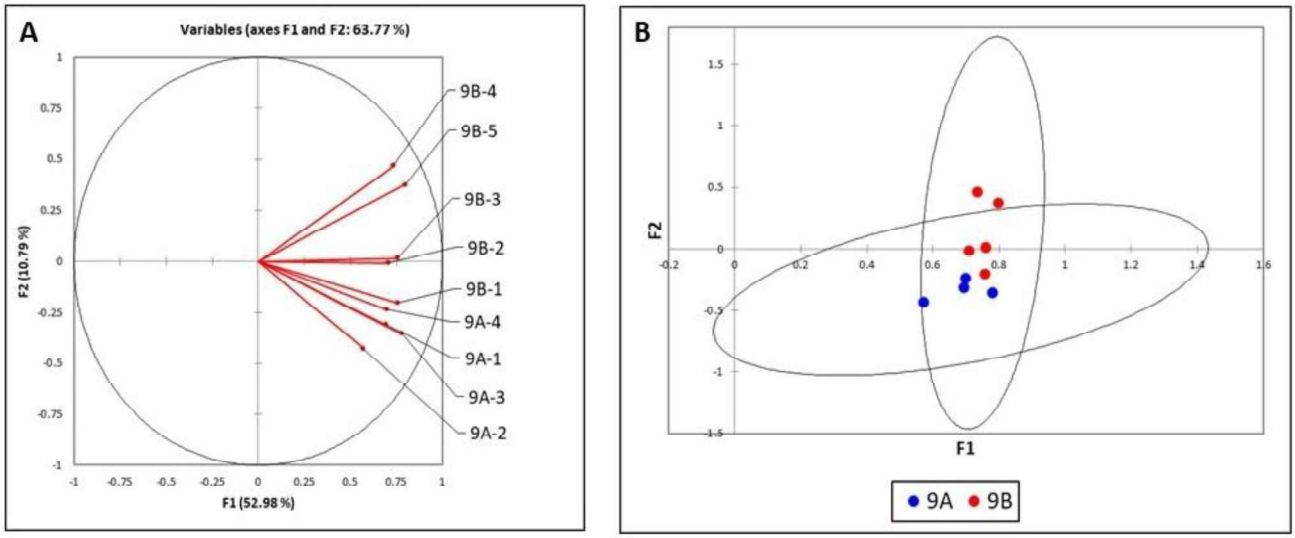

Figure 18. Statistical analysis of TRFLP of the fungal communities in corn roots of field 9. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 10

Site B produced 21 bu/ac more than site B (Site A: 202.54bu/ac vs. Site B: 181.56 bu/ac).

A summary of the soil chemical analysis and yield of field 10 is presented in Table 11. Some of the samples received for field 10 did not have an adequate amount of soil to complete the full soil health test and some samples are missing values for certain parameters. The data presented in table 4 is representative of the samples that had reported values only. A full list of samples and the reported parameters can be found in Appendix 1.

In this field site B had higher phosphorus (57.6 ppm vs 36.8 ppm), potassium (181.8 ppm vs 132.4 ppm), percent saturation phosphorus (10% vs 5.2%) and percent saturation potassium (2.1% vs 1.76%). For this soil type the percent phosphorus in site B is considered high and good for site A. The percent saturation potassium for site B was within the ideal range while site A was below.

Site B had a higher K/Mg ratio (0.31 vs 0.13) than site A and was within the ideal range while site A was below.

Both sites had similar GFI (61.4 and 63.6) and SHI (32.4 and 34.6). For both sites, the GFI and SHI values were considered to be mediocre.

While the GFI and SHI values are similar for the 2 sites, the K/Mg ration and higher percent saturation phosphorus and potassium in site B could be contributing to the higher yields.

Table 11. Soil Analysis of Field 10.

	Report C20212-10122	
Parameters	**10A**	**10B**
Yield bu/ac	181.56	202.54
Organic Matter (OM, %)	5.74	6.54
Phopsphorus (Bicarb, ppm)	36.80	57.60
Phopsphorus (Bray, ppm)	67.80	143.20
Potassium (K, ppm)	132.40	181.80
Magnesium (Mg, ppm)	304.00	180.20
Calcium (Ca, ppm)	2694.00	4020.00
Sodium (Na, ppm)	14.20	14.00
Sulfur (S, ppm)	11.20	22.20
Zinc (Zn, ppm)	4.14	13.08
Manganese (Mn, ppm)	14.40	21.60
Iron (Fe, ppm)	89.80	95.80
Copper (Cu, ppm)	4.74	5.10
Boron (B, ppm)	0.52	0.62
Aluminum (Al, ppm)	827.60	496.20
CEC (meq/ 100g)	19.26	22.10
K/Mg Ratio	0.13	0.31
General Fertility Index (GFI)	61.40	63.60
Percent Base Saturation %K	1.76	2.10
%Mg	13.16	6.80
%Ca	83.98	90.90
%H	0.92	0.00
%Na	0.32	0.28
pH	7.60	7.70
Buffer pH		
EC (ms/cm)	0.35	0.41
Saturation %P	5.20	10.00
Saturation %Al	0.02	0.00
Nitrate-N (ppm)	15.50	16.25
Chloride (ppm)	10.75	11.00
Potential Mineralizable Nitrogen (PMN, ppm)	31.80	37.75
Water Extracted Organic C (ppm)	161.00	188.00
Water Extracted Inorganic N (ppm)	31.48	30.10
Water Extracted Organic N (ppm)	31.03	24.90
Solvita CO2-C (ppm)	71.50	65.25
Reactive C (ppm)	893.00	891.75
Soil Health Index	32.40	34.60
%Microbial Active Carbon (MAC)	44.98	34.55
Organic C:N ratio	5.35	7.68
NRCS Soil Health Calculations	10.28	10.88
Biological Soil Quality	4.00	4.00
Estimated Nitrogen Release (ENR, lb/ac/year)	79.50	75.50
Water extracted total N	62.50	55.00
Water extracted Soil Nitrate	21.50	21.50
Water extracted Soil Ammonium	10.00	9.00

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site A were similar to each other, as evident from the clustering of the samples on the bottom right quadrant of the graph (Figure 19 A). The root's bacterial populations from site B were also similar to each other, as indicated by the clustering of the samples on the top right quadrant of the graph (Figure 19A). Although the bacterial communities from sites A and B were somehow different (grouped in clusters), the differences were not statistically significant (Figure 19B). A similar pattern was observed in the case of the fungal communities (Figure 20).

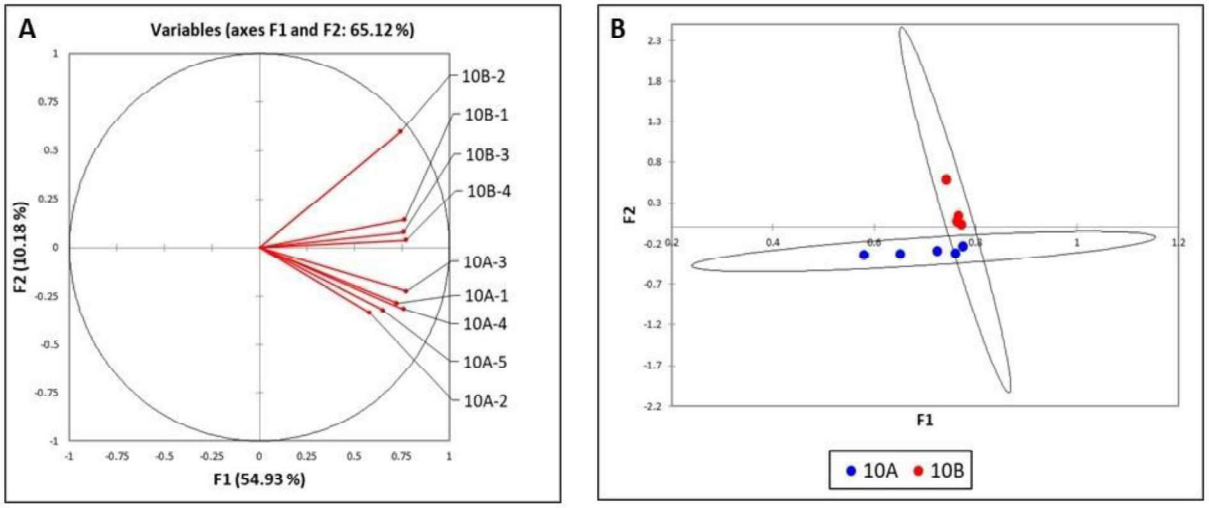

Figure 19. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 10. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

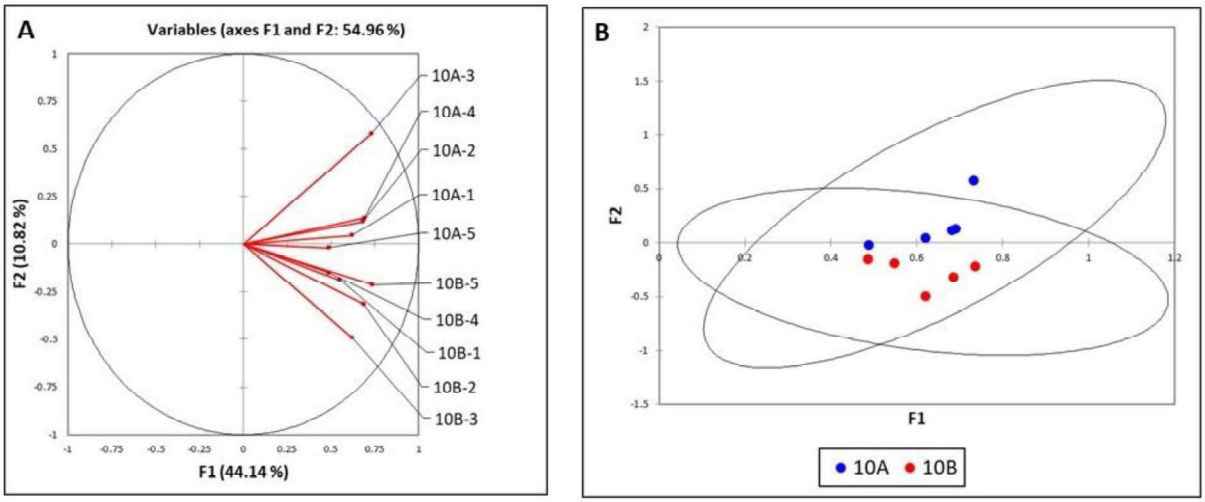

Figure 20. Statistical analysis of TRFLP of the fungal communities in corn roots of field 10. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 11

Site B produced 38.61 bu/ac more than site A (Site B: 205.16 bu/ac vs. Site A: 166.55 bu/ac).

A summary of the soil chemical analysis and yield of field 11 is presented in Table 12. Some of the samples received for field 11 did not have an adequate amount of soil to complete the full soil health test and some samples are missing values for certain parameters. The data presented in table 4 is representative of the samples that had reported values only. A full list of samples and the reported parameters can be found in Appendix 1.

In this field both sites had similar organic matter content (4.02% and 4.32%), potassium (123.4 ppm and 124.6 ppm), percent saturation potassium (1.86% and 1.78%) and pH (7.6 and 7.04).

Site B had slightly higher phosphorus (26.8 ppm and 18.8 ppm) and nearly triple the percent saturation phosphorus (7.6 % and 2.2%). For this soil type, the percent saturation phosphorus for site B is considered high and for site A it is considered low. Both sites also have similar pH values (7.6 and 7.04) and low to very low K/Mg ratios (0.124 and 0.098).

Site B had a higher GFI (62.8 and 52.4) and SHI (33 and 27.8) than site A. The GFI and SHI for site B is considered mediocre. The GFI and SHI for site A is considered low.

Site B also had higher microbial respiration (80 ppm vs 68.6 ppm) and reactive carbon (855.5 ppm and 789.6 ppm) than site A.

Table 12. Soil Analysis of Field 11.

	Report C20212-10122	
Parameters	**11A**	**11B**
Yield bu/ac	166.55	205.16
Organic Matter (OM, %)	4.02	4.32
Phopsphorus (Bicarb, ppm)	18.8	26.8
Phopsphorus (Bray, ppm)	29.2	48.4
Potassium (K, ppm)	123.4	124.6
Magnesium (Mg, ppm)	307	398.8
Calcium (Ca, ppm)	2808	2572
Sodium (Na, ppm)	15.4	16.8
Sulfur (S, ppm)	9.6	9.6
Zinc (Zn, ppm)	3.18	3
Manganese (Mn, ppm)	66.2	29.2
Iron (Fe, ppm)	62.4	73.8
Copper (Cu, ppm)	2.34	2.74
Boron (B, ppm)	0.5	0.4
Aluminum (Al, ppm)	699	837.6
CEC (meq/ 100g)	16.94	18.22
K/Mg Ratio	0.124	0.098
General Fertility Index (GFI)	52.4	62.8
Percent Base Saturation %K	1.86	1.78
%Mg	15.12	18.32
%Ca	82.82	70.34
%H	0	9.2
%Na	0.4	0.4
pH	7.6	7.04
Buffer pH		6.9
EC (ms/cm)	0.302	0.235
Saturation %P	2.2	7.6
Saturation %Al	0	0.1
Nitrate-N (ppm)	12.8	5
Chloride (ppm)	12.6	10
Potential Mineralizable Nitrogen (PMN, ppm)	38.8	42.5
Water Extracted Organic C (ppm)	128.4	178
Water Extracted Inorganic N (ppm)	21.72	14.75
Water Extracted Organic N (ppm)	22.28	20.25
Solvita CO2-C (ppm)	68.6	80
Reactive C (ppm)	789.6	855.5
Soil Health Index	27.8	33
%Microbial Active Carbon (MAC)	54.08	45.5
Organic C:N ratio	6.2	9.3
NRCS Soil Health Calculations	9.32	11.85
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	77.6	85
Water extracted total N	42	35
Water extracted Soil Nitrate	17.2	10.5
Water extracted Soil Ammonium	4.6	4

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities (Figure 21) nor on the fungal communities (Figure 22) of roots from sites A and B in this field.

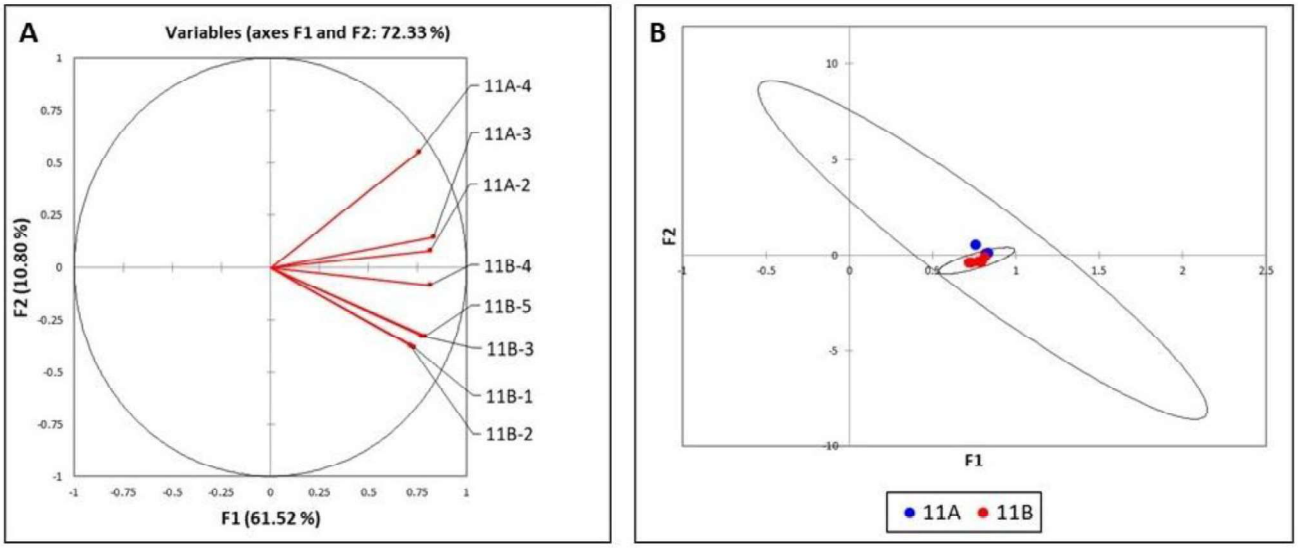

Figure 21. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 11. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

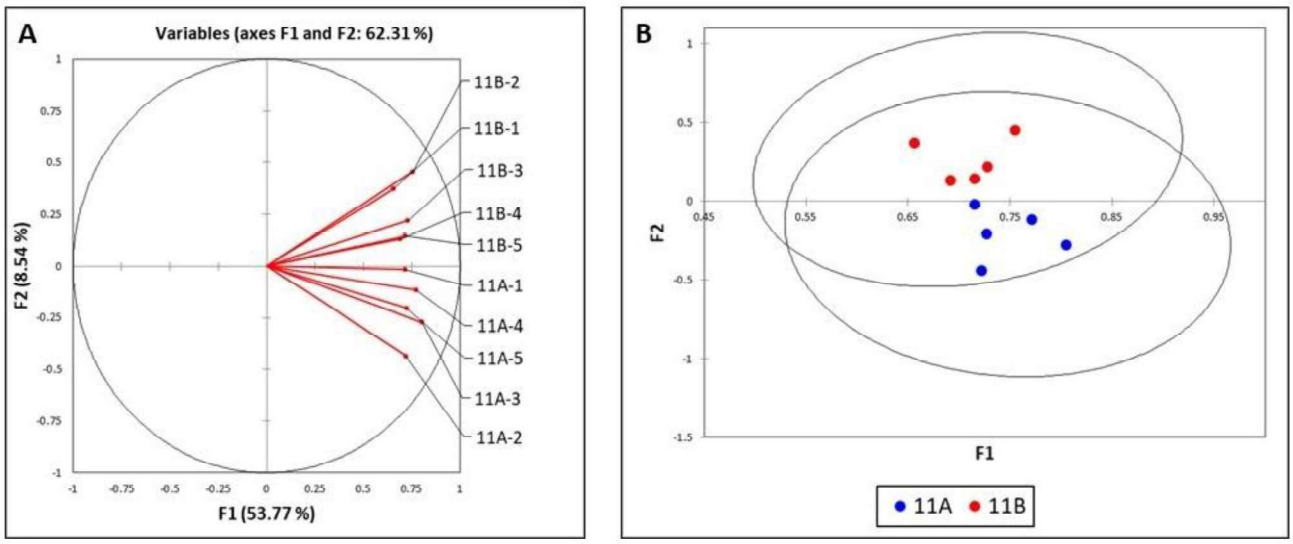

Figure 22. Statistical analysis of TRFLP of the fungal communities in corn roots of field 11. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 12

Site B produced 28.28 bu/ac more than site A (Site B: 250.98 bu/ac vs. Site A: 222.70 bu/ac).

A summary of the soil chemical analysis and yield of field 12 is presented in Table 13.

In this field, site B had higher phosphorus (131.8 ppm vs 77.8 ppm), potassium (262.4 ppm vs 215.6 ppm), percent saturation phosphorus (61% vs 34.8%) and percent saturation potassium (5.84% vs 3.68%) than site A. For the soil type in both sites, the percent saturation phosphorus is considered high, while the percent saturation potassium is on the upper end of the idea range for site B and on the lower end of the optimal range for site A.

Site A had higher GFI (75.6 vs 72.6) and SHI (41.4 vs. 37.6). Both sites had good GFI values and mediocre/good SHI values.

Site A had a K/Mg ratio (0.25 vs 0.41) that was within the ideal range while site B had a value that was higher than the ideal range. Site A also had higher microbial respiration (68.4ppm vs 57 ppm) and reactive carbon (813.4 ppm vs 736 ppm). The amount of reactive carbon recorded for site A is considered very high and site B is considered high.

Table 13. Soil Analysis of Field 12

	Report C20204-10015	
Parameters	**12A**	**12B**
Yield bu/ac	222.70	250.98
Organic Matter (OM, %)	3.96	3.24
Phopsphorus (Bicarb, ppm)	77.8	131.8
Phopsphorus (Bray, ppm)	218.2	390.8
Potassium (K, ppm)	215.6	262.4
Magnesium (Mg, ppm)	259.8	197
Calcium (Ca, ppm)	2148	1586
Sodium (Na, ppm)	18.4	16.8
Sulfur (S, ppm)	11.6	13.4
Zinc (Zn, ppm)	14.7	18.5
Manganese (Mn, ppm)	45.4	19.2
Iron (Fe, ppm)	113.2	149.8
Copper (Cu, ppm)	5.64	4.42
Boron (B, ppm)	0.46	0.3
Aluminum (Al, ppm)	804.2	824
CEC (meq/ 100g)	14.88	11.5
K/Mg Ratio	0.25	0.41
General Fertility Index (GFI)	75.6	72.6
Percent Base Saturation %K	3.68	5.84
%Mg	14.6	14.26
%Ca	71.96	68.98
%H	9.26	10.24
%Na	0.56	0.64
pH	7.04	6.32
Buffer pH	6.9	6.9
EC (ms/cm)	0.214	0.216
Saturation %P	34.8	61
Saturation %Al	0.12	0.38
Nitrate-N (ppm)	2.4	3.6
Chloride (ppm)	11.8	14.6
Potential Mineralizable Nitrogen (PMN, ppm)	38.8	34.8
Water Extracted Organic C (ppm)	129.6	108.8
Water Extracted Inorganic N (ppm)	12.78	10.58
Water Extracted Organic N (ppm)	19.22	25.42
Solvita CO2-C (ppm)	68.4	57
Reactive C (ppm)	813.4	736
Soil Health Index	41.4	37.6
%Microbial Active Carbon (MAC)	51.7	52.76
Organic C:N ratio	8.48	4.54
NRCS Soil Health Calculations	9.85	7.72
Biological Soil Quality	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	77.6	69.6
Water extracted total N	32	36
Water extracted Soil Nitrate	9.6	8
Water extracted Soil Ammonium	3.2	2.8

NRCS soil health calculations based on the Haney test results.

Microbial communities

No differences were found in the bacterial communities (Figure 23) nor on the fungal communities (Figure 24) of roots from sites A and B in this field.

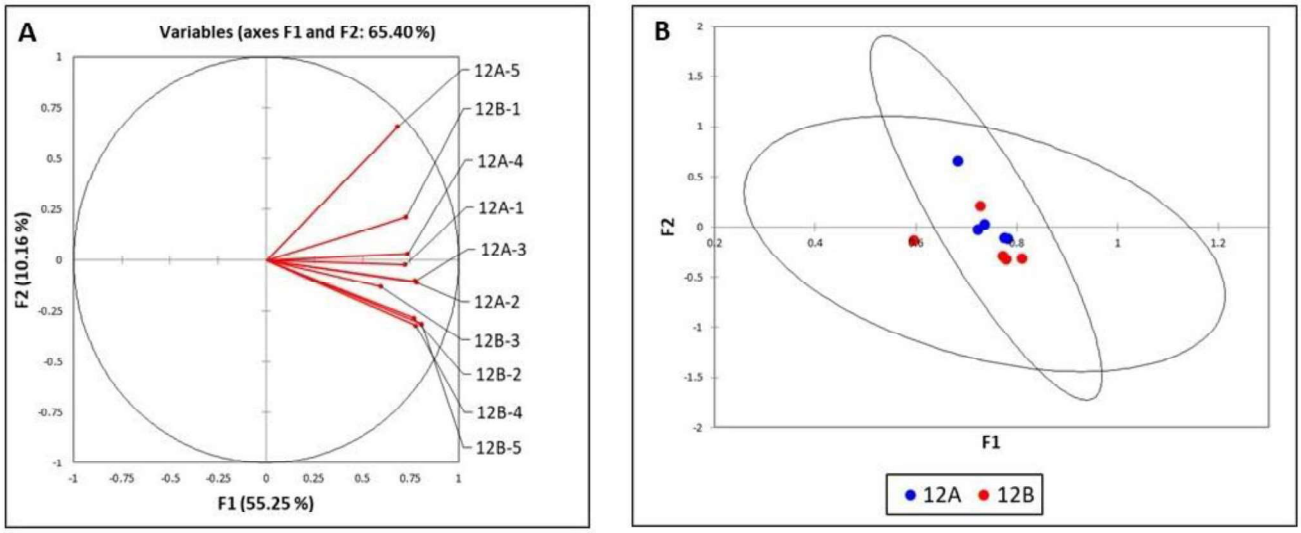

Figure 23. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 12. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

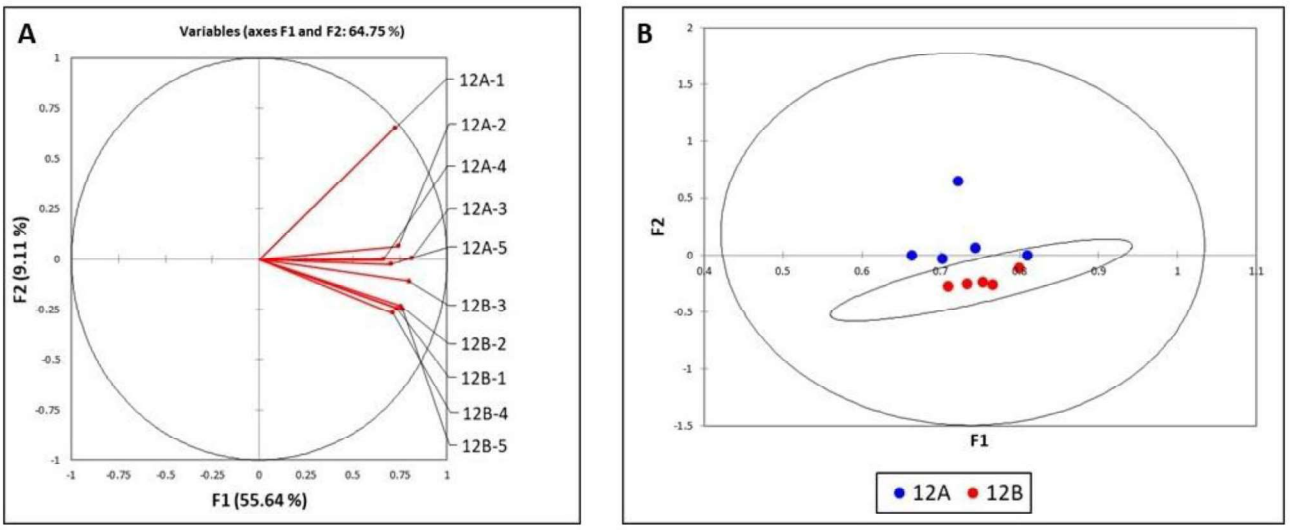

Figure 24. Statistical analysis of TRFLP of the fungal communities in corn roots of field 12. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 13

Site A produced 69.19 bu/ac more than site B (Site A: 206.64 bu/ac vs. Site B: 137.45 bu/ac).

A summary of the soil chemical analysis and yield of field 13 is presented in Table 14.

In this field Site A had higher organic matter content (5.32% vs 3.88%) than site B.

Both sites had similar phosphorus (33.6 ppm and 30.6 ppm), potassium (176.6 ppm and 142 ppm) and percent saturation phosphorus (8% and 8.6%) and potassium (2.22% and 2.06%).

Site A had a higher GFI (70 vs 64.2) and SHI (37.4 vs 33.6) than site B. Both sites had good GFI values and mediocre SHI values.

Site A had a more acidic soil (pH 5.94 vs 6.94) and a higher K/Mg ratio (0.17 vs 0.096). The K/Mg ratio for site A is below the ideal range and considered low and the ratio for site B is considered very low.

Site B had higher microbial respiration (87 ppm vs 62.8 ppm), while site A had more reactive carbon (837.4 ppm vs 685.4 ppm). Both sites had high respiration rates indicating a good balance of biological activity and organic matter.

Table 14. Soil Analysis of Field 13

	Report C20226-10175	
Parameters	**13A**	**13B**
Yield bu/ac	206.64	137.45
Organic Matter (OM, %)	5.32	3.88
Phopsphorus (Bicarb, ppm)	33.6	30.6
Phopsphorus (Bray, ppm)	63.6	61.8
Potassium (K, ppm)	176.6	143
Magnesium (Mg, ppm)	320.4	464.6
Calcium (Ca, ppm)	2344	2408
Sodium (Na, ppm)	19.4	24
Sulfur (S, ppm)	7.6	9.6
Zinc (Zn, ppm)	4.6	5.48
Manganese (Mn, ppm)	6.4	17.6
Iron (Fe, ppm)	138.2	85.2
Copper (Cu, ppm)	2.5	1.26
Boron (B, ppm)	0.7	0.58
Aluminum (Al, ppm)	1025.8	903.6
CEC (meq/ 100g)	20.42	17.86
K/Mg Ratio	0.17	0.096
General Fertility Index (GFI)	70	64.2
Percent Base Saturation %K	2.22	2.06
%Mg	13.2	21.7
%Ca	57.76	67.4
%H	26.44	8.3
%Na	0.4	0.6
pH	5.94	6.94
Buffer pH	6.54	6.9
EC (ms/cm)	0.232	0.226
Saturation %P	8	8.6
Saturation %Al	0.43	0.1
Nitrate-N (ppm)	6.6	3.8
Chloride (ppm)	10.6	25.4
Potential Mineralizable Nitrogen (PMN, ppm)	36.6	44.2
Water Extracted Organic C (ppm)	238.4	239.6
Water Extracted Inorganic N (ppm)	18.4	16
Water Extracted Organic N (ppm)	23.6	22
Solvita CO2-C (ppm)	62.8	87
Reactive C (ppm)	837.4	685.4
Soil Health Index	37.4	33.6
%Microbial Active Carbon (MAC)	26.58	36.36
Organic C:N ratio	10.76	11.5
NRCS Soil Health Calculations	11.02	13.3
Biological Soil Quality	3.8	4
Estimated Nitrogen Release (ENR, lb/ac/year)	73.2	88.4
Water extracted total N	42	38
Water extracted Soil Nitrate	13.8	10.4
Water extracted Soil Ammonium	4.4	5.6

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site A were similar to each other, as evident from the clustering of the samples on the bottom right quadrant of the graph (Figure 24A). The root's bacterial populations from site B were also similar to each other, as indicated by the clustering of the samples on the top right quadrant of the graph (Figure 24A). Although the bacterial communities from sites A and B were somehow different (grouped in clusters), the differences were not statistically significant (Figure 24B). Similar results were obtained with the fungal communities (Figure 25). There is a clear trend showing differences in microbial compositions at the two locations.

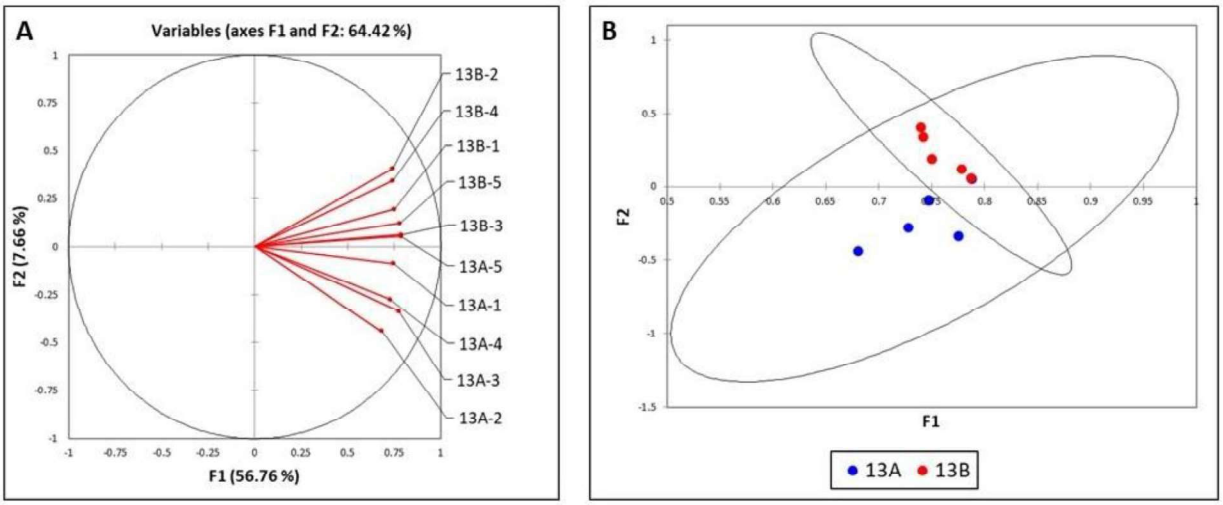

Figure 25. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 13. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

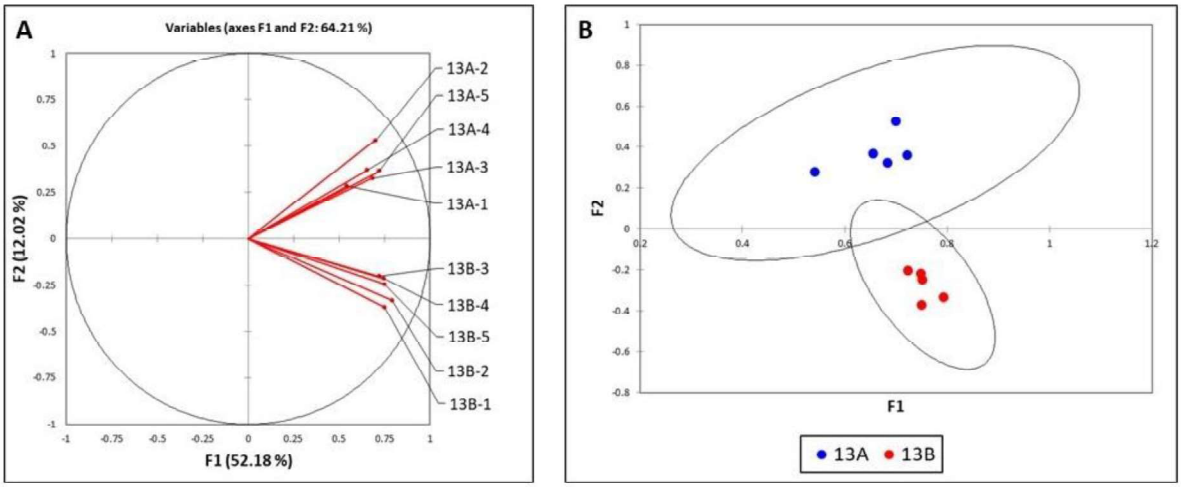

Figure 26. Statistical analysis of TRFLP of the fungal communities in corn roots of field 13. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Field 14

Site B produced 92.42 bu/ac more than site A (Site B: 238.01 bu/ac vs. Site A: 145.59 bu/ac).

A summary of the soil chemical analysis and yield of field 14 is presented in Table 15. Some of the samples received for field 14 did not have an adequate amount of soil to complete the full soil health test and some samples are missing values for certain parameters. The data presented in table 4 is representative of the samples that had reported values only. A full list of samples and the reported parameters can be found in Appendix 1.

In this field, both sites had similar organic matter (3.72% and 3.28%) content and low pH values (5.1 and 5.96).

Site A had higher phosphorus (46.2 ppm vs 28.8 ppm) and percent saturation phosphorus (9.4% vs 6.2%). For this soil type 9.4% is considered good and 6.2% is considered mediocre.

Site B had higher potassium (121.4 ppm vs 81.2 ppm) and percent saturation potassium (4.3% vs 1.94%). For this soil type, 4.3% is within the ideal range while 1.94% is considered low.

The nitrate levels in field site B were much higher than at site A (30.6 vs 1.6) indicating that nitrogen levels may play a role in the lower yields at site A. Tis was also seen with the total water extractable levels of N (32 vs 14) and that of ammonium (4.2 vs 2.4).

Site B had a higher GFI (81 vs 46) and SHI (43.8 vs 25). A GFI of 81 is considered high and a GFI of 46 is considered mediocre. An SHI of 43 is considered mediocre and an SHI of 25 is considered low.

Site B had higher microbial respiration (60.4 ppm vs 44 ppm) and both sites had similar amounts of reactive carbon (828.2 ppm and 842.6 ppm). Both sites had mediocre microbial respiration and very high levels of reactive carbon.

Table 15. Soil Analysis of Field 14

	Report C20212-10122	
Parameters	14A	14B
Yield bu/ac	145.59	238.01
Organic Matter (OM, %)	3.72	3.28
Phopsphorus (Bicarb, ppm)	46.2	28.8
Phopsphorus (Bray, ppm)	107	54
Potassium (K, ppm)	81.2	121.4
Magnesium (Mg, ppm)	37.8	104
Calcium (Ca, ppm)	270	832
Sodium (Na, ppm)	13.2	13.6
Sulfur (S, ppm)	21.8	13.2
Zinc (Zn, ppm)	6.54	8.26
Manganese (Mn, ppm)	6.2	12.6
Iron (Fe, ppm)	78.2	64.4
Copper (Cu, ppm)	0.5	0.6
Boron (B, ppm)	0.18	0.4
Aluminum (Al, ppm)	1464.6	1097.2
CEC (meq/ 100g)	11.04	7.32
K/Mg Ratio	0.7	0.356
General Fertility Index (GFI)	46	81
Percent Base Saturation %K	1.94	4.3
%Mg	2.86	11.94
%Ca	12.46	57.28
%H	82.22	25.66
%Na	0.56	0.82
pH	5.1	5.96
Buffer pH	6.24	6.84
EC (ms/cm)	0.192	0.392
Saturation %P	9.4	6.2
Saturation %Al	5.38	1.6
Nitrate-N (ppm)	1.6	30.6
Chloride (ppm)	6	8.2
Potential Mineralizable Nitrogen (PMN, ppm)	29.8	36
Water Extracted Organic C (ppm)	82.4	76.8
Water Extracted Inorganic N (ppm)	18.24	19.26
Water Extracted Organic N (ppm)	8.3	12.74
Solvita CO2-C (ppm)	44	60.4
Reactive C (ppm)	828.2	841.6
Soil Health Index	25	43.8
%Microbial Active Carbon (MAC)	77.02	78.86
Organic C:N ratio	12.5	7.36
NRCS Soil Health Calculations	5.3	7.48
Biological Soil Quality	3.8	4
Estimated Nitrogen Release (ENR, lb/ac/year)	59.6	72
Water extracted total N	14	32
Water extracted Soil Nitrate	16	15.2
Water extracted Soil Ammonium	2.4	4.2

NRCS soil health calculations based on the Haney test results.

Microbial communities

The bacterial communities of roots from site A were similar to each other, as evident from the clustering of the samples on the bottom right quadrant of the graph (Figure 26A). The root's bacterial populations from site B were also similar to each other, as indicated by the clustering of the samples on the top right quadrant of the graph (Figure 26A). Although the bacterial communities from sites A and B were somehow different (grouped in clusters), the differences were not statistically significant (Figure 26B).

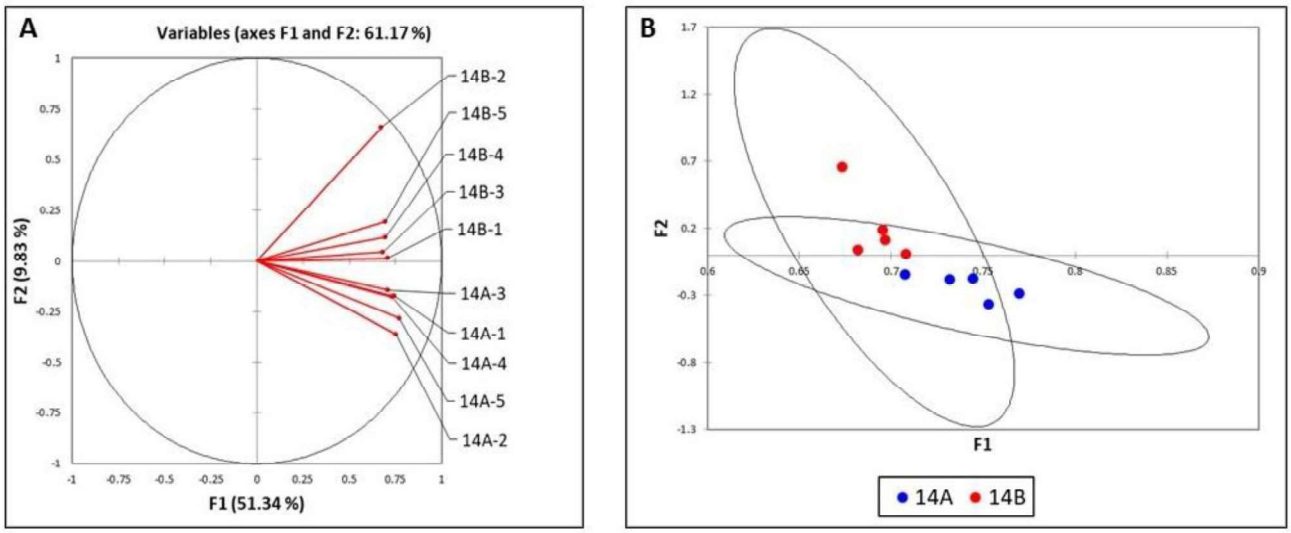

Figure 26. Statistical analysis of TRFLP of the bacterial communities in corn roots of field 14. Bacterial communities are represented as vectors (A) and as points with 95% confidence circles (B).

The fungal communities of roots from site A were similar to each other, as evident from the clustering of the samples on the bottom right quadrant of the graph (Figure 27A). The root's fungal populations from site B were also similar to each other, as indicated by the clustering of the samples on the top right quadrant of the graph (Figure 27A). Although the fungal communities from sites A and B were clearly vastly different (grouped in clusters), the differences were significant (Figure 27B). The large difference between the GFI (46 for site A and 81 for site B) and the SHI (25 for site A and 43 for site B) are likely driving the difference between the microbial composition of roots from these sites.

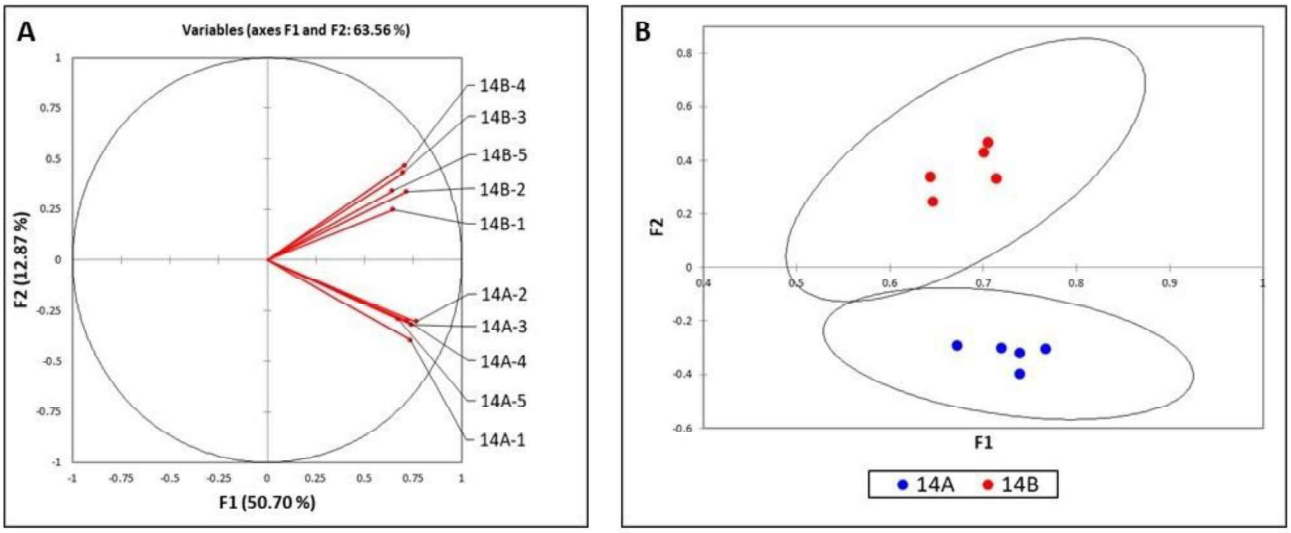

Figure 27. Statistical analysis of TRFLP of the fungal communities in corn roots of field 14. Fungal communities are represented as vectors (A) and as points with 95% confidence circles (B).

Summary of Results (Table 15)

- Remote sensing technology (aerial imaging) identified highly productive vs less productive sites at 13 of the 14 fields studied (93% success, differences bigger than 5 bu/ac).
- Higher General Fertility index (GFI) and Soil Health Index (SHI) correlated with higher yields on 11 of the 14 fields (79% success).
- The Soil health Index predicted the sites having the greatest yield differences. Sites with low or no yield differences had similar SHI values.
- Bacteria population differences were reflected in soils with the greatest yield differences.
- Fungal populations were more indicative of yield variance in the soils at the specific sites.

Analysis of the data from the three fields were the higher Soil Health Index did not match higher yields (field 1, 3 and 12), point to possible explanations.

Field 1: Although the fertility and soil health of site A is better than on site B, site B produced 51 bu/ac more than site A. Site A had a CEC = 5.44 (sand) and a 1.7% organic matter, while site B had a CEC = 10.5 (sandy loam) and 3.4% organic matter. These differences may have been key during the drought experienced during June - July 2020.

Field 3: Site A produced 18.8 bu/ac more than site B. Differences in micronutrient concentrations such as Zn, Mn, S, Fe and B (all higher in site A) may be contributing to the higher yields of this site. At A&L we are working on compiling a robust data base to better weight the impact of micronutrients on the Soil Health Index.

Field 12: Site B produced 28.4 bu/ac more than site A. In this field, the higher percentage saturation of potassium of site B may be the driver of higher yield in this site (5.84% vs 3.68%).

VitTellus is a Soil Health Test which assesses the chemical, physical and biological balance of the soil, and leads to agronomic strategies to improve soil health which drives greater nutrient utilization, higher crop yields and greater farm profitability.

This study provides clear evidence of the site variability in yields that if addressed could help growers produce better crops.

Tests with more replicates per farm likely would have increased the accuracy of the results.

Table 15. Summary of the results

	Yield	Differences in bu/ac (field with higher yield)	GFI	SHI
1A	172.7	51.3 (B)	79	42.2
1B	224		70	36.6
2A	141.46	9.7 (A)	70	36.6
2B	131.76		69.4	36.4
3A	227.77	18.8 (A)	73.8	39
3B	208.98		80	42.6
4A	230.21	40.4 (A)	70.6	37.4
4B	189.78		67.6	36.2
5A	176.12	20.8 (B)	55.8	29.4
5B	196.95		58	30.6
6A	229.53	49.2 (A)	73.8	37.8
6B	180.34		64	34.2
7A	216.2	3 (A)	77.8	42
7B	213.2		78.8	42.6
8A	251.72	55.4 (A)	63.2	33.4
8B	196.31		50.4	26
9A	176.04	7.5 (B)	66	35.4
9B	183.57		67.8	35.75
10A	181.56	20.9 (B)	61.4	32.4
10B	202.54		63.6	34.6
11A	166.55	38.6 (B)	52.4	27.8
11B	205.16		62.8	33
12A	222.7	28.3 (B)	75.6	41.4
12B	250.98		72.6	37.6
13A	206.64	69.2 (A)	70	37.4
13B	137.45		64.2	33.6
14A	145.59	92.4 (B)	46	25
14B	238.01		81	43.8

Conclusions

The soil health test gives a complete overview of the chemical status of a soil and allows us to identify the differences between different production areas. It also provides growers with the optimal ranges of those chemical factor that highly correlate with yields and beneficial microbial activities.

Appendix

The tables presented below correspond to the summary of the results of the soil chemical analysis. Values highlighted in red were considered outliers and removed from the results presented in the body of this report.

Field 1: chemical analysis

	Report # C20204-10015									
Parameters	1A-1	1A-2	1A-3	1A-4	1A-5	1B-1	1B-2	1B-3	1B-4	1B-5
Yield (bu/ac)	172.7	172.7	172.7	172.7	172.7	224.0	224.0	224.0	224.0	224.0
Organic Matter (OM, %)	1.6	1.7	1.7	1.7	1.7	3.4	3.4	3.4	3.3	3.5
Phopsphorus (Bicarb, ppm)	58	58	51	52	59	48	51	47	50	43
Phopsphorus (Bray, ppm)	164	163	154	155	166	109	138	119	105	118
Potassium (K, ppm)	60	79	77	67	74	52	75	72	57	62
Magnesium (Mg, ppm)	112	110	117	124	120	130	154	153	159	145
Calcium (Ca, ppm)	530	560	560	530	620	1020	1100	1210	1190	1160
Sodium (Na, ppm)	11	12	10	9	12	10	10	12	11	14
Sulfur (S, ppm)	6	6	5	6	6	8	10	9	9	9
Zinc (Zn, ppm)	8.6	7.4	7.3	8.7	9	16.8	20.7	19.1	12	17.5
Manganese (Mn, ppm)	22	22	21	20	20	22	23	25	22	24
Iron (Fe, ppm)	108	114	109	105	110	85	88	92	84	89
Copper (Cu, ppm)	2.4	2.4	2.5	2.6	2.7	3.2	3.8	3.8	3.4	3.7
Boron (B, ppm)	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.2	0.2
Aluminum (Al, ppm)	772	749	682	687	704	647	737	772	735	707
CEC (meq/ 100g)	5	5.2	5.2	5.1	6.7	8.7	10.6	12.3	8.7	12
K/Mg Ratio	0.16	0.22	0.2	0.17	0.19	0.12	0.15	0.15	0.11	0.13
General Fertility Index (GFI)	76	86	83	75	75	79	71	70	66	67
Percent Base Saturation %K	3.1	3.9	3.8	3.4	2.8	1.5	1.8	1.5	1.7	1.3
%Mg	18.8	17.8	18.7	20.3	14.9	12.4	12.1	10.3	15.3	10.1
%Ca	53.3	54.3	53.8	52.2	46.1	58.3	51.9	49	68.8	48.3
%H	23.9	23	22.8	23.4	35.5	27.3	33.8	38.7	13.7	39.8
%Na	1	1	0.8	0.8	0.8	0.5	0.4	0.4	0.6	0.5
pH	5.7	5.6	5.8	6	6	5.6	5.6	5.6	5.8	5.5
Buffer pH	6.9	6.9	6.9	6.9	6.8	6.8	6.7	6.6	6.9	6.6
EC (ms/cm)	0.12	0.13	0.12	0.12	0.13	0.17	0.19	0.2	0.19	0.2
Saturation %P	27	28	29	29	30	22	24	20	18	21
Saturation %Al	2.2	2.4	1.6	1.2	0.9	1.2	1.2	1.2	1	1.1
Nitrate-N (ppm)	2	2	2	1	2	4	5	6	5	7
Chloride (ppm)	8	8	13	9	9	12	9	9	26	14
Potential Mineralizable Nitrogen (PMN, ppm)	29	30	32	31	31	30	32	27	32	23
Water Extracted Organic C (ppm)	12	32	28	30	24	58	38	30	52	30
Water Extracted Inorganic N (ppm)	6.3	5.5	6	4.7	4.9	5.9	6.2	7.9	7.9	6.1
Water Extracted Organic N (ppm)	13.7	4.5	14	5.3	5.1	4.1	13.8	12.1	2.1	3.9
Solvita CO2-C (ppm)	42	44	50	46	46	44	50	38	50	30
Reactive C (ppm)	519	484	513	517	470	723	738	736	698	746
Soil Health Index	40	46	45	40	40	41	37	36	34	35
%Microbial Active Carbon (MAC)	345.8	135.9	178.6	151.7	189.6	75	131.6	127	96.2	101
Organic C:N ratio	0.9	7.1	2	5.7	4.7	14.1	2.8	2.5	24.8	7.7
NRCS Soil Health Calculations	4.4	5.1	5.4	5.4	4.8	5.3	5.5	4.2	5.7	3.7
Biological Soil Quality	3	4	4	4	4	4	4	3	4	3
Estimated Nitrogen Release (ENR, lb/ac/year)	58	60	64	62	62	60	64	54	64	46
Water extracted total N	20	10	20	10	10	10	20	20	10	10
Water extracted Soil Nitrate	4	3	3	3	3	4	4	6	5	5
Water extracted Soil Ammonium	2	3	3	3	2	2	2	2	3	1

Field 2: chemical analysis

	Report # C20226-10175									
Parameters	2A-1	2A-2	2A-3	2A-4	2A-5	2B-1	2B-2	2B-3	2B-4	2B-5
Yield (bu/ac)	141.5	141.5	141.5	141.5	141.5	131.8	131.8	131.8	131.8	131.8
Organic Matter (OM, %)	4.4	4.2	4.5	4.4	4.3	4.4	4.4	4.4	4.4	4.2
Phopsphorus (Bicarb, ppm)	43	48	51	40	50	34	48	40	38	40
Phopsphorus (Bray, ppm)	89	123	121	88	114	68	112	73	73	96
Potassium (K, ppm)	118	150	132	146	138	121	119	129	118	139
Magnesium (Mg, ppm)	247	287	253	273	270	250	233	252	263	273
Calcium (Ca, ppm)	1470	1710	1490	1600	1600	1530	1500	1580	1610	1690
Sodium (Na, ppm)	18	22	16	17	18	16	17	18	21	18
Sulfur (S, ppm)	13	21	12	12	11	9	12	10	11	11
Zinc (Zn, ppm)	3.5	5.9	4.7	3.7	5	4.2	7.6	4.5	4.6	5.3
Manganese (Mn, ppm)	3	4	4	4	4	3	4	3	4	3
Iron (Fe, ppm)	177	181	174	176	178	181	177	181	188	181
Copper (Cu, ppm)	2	2.1	2.1	2	2.1	1.8	1.8	2.1	1.9	2
Boron (B, ppm)	0.5	0.6	0.5	0.5	0.5	0.5	0.7	0.6	0.6	0.6
Aluminum (Al, ppm)	891	955	861	887	893	894	856	852	897	897
CEC (meq/ 100g)	14.6	18.6	13.5	15.5	15.5	13.7	17	15.2	15.4	15.9
K/Mg Ratio	0.15	0.16	0.16	0.16	0.16	0.15	0.16	0.16	0.14	0.15
General Fertility Index (GFI)	71	64	73	73	69	71	65	71	68	72
Percent Base Saturation %K	2.1	2.1	2.5	2.4	2.3	2.3	1.8	2.2	2	2.2
%Mg	14.1	12.9	15.6	14.7	14.6	15.2	11.4	13.8	14.2	14.3
%Ca	50.5	46	55	51.6	51.8	55.9	44.1	52	52.3	53
%H	32.8	38.6	26.4	30.8	30.9	26.1	42.2	31.4	31	29.9
%Na	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.6	0.5
pH	5.7	5.4	5.6	5.5	5.6	5.8	5.7	5.8	5.7	5.6
Buffer pH	6.6	6.4	6.7	6.6	6.6	6.7	6.4	6.6	6.6	6.6
EC (ms/cm)	0.21	0.36	0.22	0.32	0.25	0.18	0.19	0.18	0.19	0.19
Saturation %P	13	17	18	13	16	10	17	11	10	14
Saturation %Al	0.9	1.2	1.1	1.1	1	0.8	0.7	0.7	0.8	0.9
Nitrate-N (ppm)	3	18	6	19	10	2	1	1	1	1
Chloride (ppm)	13	15	12	18	12	13	10	12	13	15
Potential Mineralizable Nitrogen (PMN, ppm)	39	38	32	39	41	34	39	31	32	24
Water Extracted Organic C (ppm)	154	162	208	188	182	176	188	208	200	200
Water Extracted Inorganic N (ppm)	9.1	25.8	12.8	31.2	16.9	5.3	6.5	7.5	8.1	7.3
Water Extracted Organic N (ppm)	20.9	4.2	17.2	18.8	23.1	14.7	13.5	22.5	11.9	12.7
Solvita CO2-C (ppm)	69	66	48	69	75	55	69	46	50	32
Reactive C (ppm)	677	670	731	735	749	682	745	738	765	737
Soil Health Index	37	34	38	38	36	37	34	37	36	38
%Microbial Active Carbon (MAC)	44.6	40.6	23	36.5	41	31	36.5	21.9	25	15.8
Organic C:N ratio	7.4	38.6	12.1	10	7.9	12	13.9	9.2	16.8	15.7
NRCS Soil Health Calculations	10.5	8.6	8.6	10.6	11.6	8.7	10.1	8.9	8.2	6.4
Biological Soil Quality	4	4	4	4	4	4	4	4	4	3
Estimated Nitrogen Release (ENR, lb/ac/year)	78	76	64	78	82	68	78	62	64	48
Water extracted total N	30	30	30	50	40	20	20	30	20	20
Water extracted Soil Nitrate	6	24	11	30	15	3	4	4	4	4
Water extracted Soil Ammonium	3	2	2	1	2	2	3	4	4	3

Field 3: chemical analysis

	Report # C20212-10122									
Parameters	3A-1	3A-2	3A-3	3A-4	3A-5	3B-1	3B-2	3B-3	3B-4	3B-5
Yield (bu/ac)	227.8	227.8	227.8	227.8	227.8	209.0	209.0	209.0	209.0	209.0
Organic Matter (OM, %)	4.1	3.9	4.4	3.9	3.9	4.2	4.1	4.1	3.8	4
Phopsphorus (Bicarb, ppm)	42	26	41	37	37	38	42	38	22	33
Phopsphorus (Bray, ppm)	99	53	81	70	65	92	74	65	45	77
Potassium (K, ppm)	163	129	172	138	149	167	172	185	148	202
Magnesium (Mg, ppm)	257	276	281	258	248	233	237	272	252	255
Calcium (Ca, ppm)	1780	1890	1880	1860	1760	1630	1610	1810	1660	1640
Sodium (Na, ppm)	15	29	15	12	15	13	16	15	15	9
Sulfur (S, ppm)	9	8	8	8	8	7	7	8	7	0
Zinc (Zn, ppm)	7.4	6.2	9	6.9	7.1	5.8	5.2	6.4	4.2	0
Manganese (Mn, ppm)	12	6	7	7	7	4	4	4	4	0
Iron (Fe, ppm)	99	92	101	97	99	103	111	117	106	0
Copper (Cu, ppm)	2.9	2.8	3.1	3	2.8	2.8	2.8	3.4	3.1	0
Boron (B, ppm)	0.3	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0
Aluminum (Al, ppm)	863	827	850	872	904	760	796	868	877	896
CEC (meq/ 100g)	17.5	13.4	14.6	16.6	14.9	15.4	14.1	13	14.4	15.7
K/Mg Ratio	0.2	0.15	0.19	0.16	0.19	0.22	0.22	0.21	0.18	0.24
General Fertility Index (GFI)	77	64	80	72	76	83	85	78	72	82
Percent Base Saturation %K	2.4	2.5	3	2.1	2.6	2.8	3.1	3.6	2.6	3.3
%Mg	12.2	17.2	16	12.9	13.9	12.6	14	17.4	14.6	13.6
%Ca	50.9	70.6	64.3	55.9	59.1	53.1	57.1	69.5	57.6	52.4
%H	34.1	8.7	16.2	28.7	24	31.1	25.3	9	24.8	30.5
%Na	0.4	0.9	0.4	0.3	0.4	0.4	0.5	0.5	0.5	0.2
pH	5.8	6	6	5.9	5.7	5.9	5.9	6	6.1	5.7
Buffer pH	6.5	6.9	6.8	6.6	6.7	6.6	6.7	6.9	6.7	6.6
EC (ms/cm)	0.19		0.18	0.17	0.17		0.16	0.17	0.16	
Saturation %P	15	8	12	10	9	16	12	10	7	11
Saturation %Al	0.6	0.6	0.5	0.5	0.9	0.5	0.6	0.6	0.5	0.8
Nitrate-N (ppm)	3		2	1	1		1	1	1	
Chloride (ppm)	10		8	9	10		10	8	9	
Potential Mineralizable Nitrogen (PMN, ppm)	42		44	38	35		38	36	33	
Water Extracted Organic C (ppm)	164		174	158	168		174	190	186	
Water Extracted Inorganic N (ppm)	15.4		13.4	11.5	12.1		10.9	14.5	14.7	
Water Extracted Organic N (ppm)	34.6		26.6	28.5	27.9		29.1	35.5	35.3	
Solvita CO2-C (ppm)	78		86	66	57		66	60	52	
Reactive C (ppm)	1020		789	957			1043		945	
Soil Health Index	41	34	42	38	40	44	45	42	38	44
%Microbial Active Carbon (MAC)	47.8		49.6	41.6	34		37.8	31.4	28.1	
Organic C:N ratio	4.7		6.5	5.5	6		6	5.4	5.3	
NRCS Soil Health Calculations	9.8		13	11	10.2		11.2	11.4	10.6	
Biological Soil Quality	4		4	4	4		4	4	4	
Estimated Nitrogen Release (ENR, lb/ac/year)	84		88	76	70		76	72	66	
Water extracted total N	50		40	40	40		40	50	50	
Water extracted Soil Nitrate	10		9	7	7		6	8	9	
Water extracted Soil Ammonium	5		4	5	5		5	7	6	

Field 4: chemical analysis

	Report # C20204-10015									
Parameters	4A-1	4A-2	4A-3	4A-4	4A-5	4B-1	4B-2	4B-3	4B-4	4B-5
Yield (bu/ac)	230.2	230.2	230.2	230.2	230.2	189.8	189.8	189.8	189.8	189.8
Organic Matter (OM, %)	4	4.1	3.9	4.1	4.1	4.3	4.2	4.2	4.1	4
Phopsphorus (Bicarb, ppm)	69	79	57	61	56	77	84	71	67	56
Phopsphorus (Bray, ppm)	184	218	159	160	136	212	240	201	187	174
Potassium (K, ppm)	145	165	128	117	111	198	131	154	168	135
Magnesium (Mg, ppm)	234	244	239	217	226	301	290	306	273	308
Calcium (Ca, ppm)	1480	1490	1560	1460	1510	1620	1550	1680	1500	1590
Sodium (Na, ppm)	13	13	14	12	15	15	15	15	14	17
Sulfur (S, ppm)	11	11	9	10	9	12	13	13	10	11
Zinc (Zn, ppm)	7.3	6.9	5	5.1	4.5	5.9	6.7	7.1	5.4	5.2
Manganese (Mn, ppm)	6	4	4	4	4	6	5	6	5	5
Iron (Fe, ppm)	109	111	109	107	112	123	122	129	121	126
Copper (Cu, ppm)	2.4	2	2	1.9	1.9	1.6	1.7	1.5	1.4	1.6
Boron (B, ppm)	0.4	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3
Aluminum (Al, ppm)	882	832	867	787	856	827	813	840	757	866
CEC (meq/ 100g)	11	11.1	11.4	10.6	12.2	12.3	11.7	12.6	11.4	12.1
K/Mg Ratio	0.19	0.21	0.17	0.16	0.15	0.2	0.14	0.15	0.19	0.14
General Fertility Index (GFI)	69	75	69	67	73	74	64	66	70	64
Percent Base Saturation %K	3.4	3.8	2.9	2.8	2.3	4.1	2.9	3.1	3.8	2.9
%Mg	17.8	18.3	17.5	17	15.5	20.3	20.6	20.3	19.9	21.2
%Ca	67.6	66.9	68.7	68.6	62.1	65.6	66	66.8	65.6	65.7
%H	10.7	10.5	10.3	11.1	19.5	9.5	10	9.3	10.2	9.6
%Na	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.6
pH	6.2	6.4	6	6.1	6	6.6	6.7	6.7	6.7	6.6
Buffer pH	6.9	6.9	6.9	6.9	6.8	6.9	6.9	6.9	6.9	6.9
EC (ms/cm)	0.22	0.22	0.2	0.21	0.2	0.23	0.21	0.23	0.23	0.23
Saturation %P	27	34	24	26	20	33	38	31	32	26
Saturation %Al	0.5	0.4	0.7	0.6	0.6	0.2	0.2	0.2	0.2	0.3
Nitrate-N (ppm)	6	6	5	6	5	6	4	5	8	7
Chloride (ppm)	12	16	15	13	21	15	14	14	14	14
Potential Mineralizable Nitrogen (PMN, ppm)	37	41	38	38	37	42	40	43	41	38
Water Extracted Organic C (ppm)	138	74	104	88	94	94	90	90	168	104
Water Extracted Inorganic N (ppm)	10.9	7.7	8.7	8.3	8.5	10.4	10.5	9.4	10.7	12.2
Water Extracted Organic N (ppm)	19.1	2.3	11.3	11.7	21.5	9.6	29.5	20.6	29.3	27.8
Solvita CO2-C (ppm)	63	75	66	66	63	78	72	82	75	66
Reactive C (ppm)	829	864	776	830	785	871	857	839	837	831
Soil Health Index	37	40	37	35	38	40	34	35	38	34
%Microbial Active Carbon (MAC)	45.4	100.8	63.2	74.7	66.7	83.4	79.6	91.4	44.4	63.2
Organic C:N ratio	7.2	32.2	9.2	7.5	4.4	9.8	3.1	4.4	5.7	3.7
NRCS Soil Health Calculations	9.6	8.4	8.7	8.6	7.4	9.7	8.4	9.3	12.1	7.9
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	74	82	76	76	74	84	80	86	82	76
Water extracted total N	30	10	20	20	30	20	40	30	40	40
Water extracted Soil Nitrate	8	5	6	6	6	6	6	6	7	8
Water extracted Soil Ammonium	3	3	3	2	3	4	5	3	4	4

Field 5: chemical analysis

	Report # C20204-10015									
Parameters	5A-1	5A-2	5A-3	5A-4	5A-5	5B-1	5B-2	5B-3	5B-4	5B-5
Yield (bu/ac)	176.1	176.1	176.1	176.1	176.1	196.9	196.9	196.9	196.9	196.9
Organic Matter (OM, %)	2.6	2.6	2.5	2.3	2.4	2.5	2.7	2.7	2.6	2.9
Phopsphorus (Bicarb, ppm)	36	31	28	25	27	25	15	21	25	20
Phopsphorus (Bray, ppm)	59	48	49	38	46	49	22	29	43	37
Potassium (K, ppm)	94	75	101	86	74	82	63	91	75	73
Magnesium (Mg, ppm)	213	190	208	182	204	207	190	229	208	228
Calcium (Ca, ppm)	1800	1720	1740	1580	1650	1370	1300	1280	1290	1400
Sodium (Na, ppm)	15	14	14	13	15	10	13	16	15	14
Sulfur (S, ppm)	9	8	8	7	8	7	7	7	7	8
Zinc (Zn, ppm)	2.9	2.8	2.8	2.8	4.8	5.7	3.8	3.9	3.8	3.9
Manganese (Mn, ppm)	25	25	29	25	28	25	23	27	25	25
Iron (Fe, ppm)	71	62	65	61	63	69	59	64	65	63
Copper (Cu, ppm)	0.9	0.9	0.9	0.8	1	1.2	0.9	0.9	0.9	0.9
Boron (B, ppm)	0.4	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.4	0.4
Aluminum (Al, ppm)	663	579	701	645	708	619	567	703	635	612
CEC (meq/ 100g)	11.1	10.4	10.7	9.7	10.2	9.2	8.7	9.9	9.6	10
K/Mg Ratio	0.14	0.12	0.15	0.15	0.11	0.12	0.1	0.12	0.11	0.1
General Fertility Index (GFI)	59	55	57	55	53	58	51	60	61	60
Percent Base Saturation %K	2.2	1.8	2.4	2.3	1.9	2.3	1.9	2.4	2	1.9
%Mg	16.1	15.2	16.2	15.7	16.7	18.7	18.2	19.3	18	18.9
%Ca	81.4	82.6	81.1	81.7	81	74.1	74.6	64.8	67.1	69.8
%H	0	0	0	0	0	4.5	4.5	12.8	12.2	8.8
%Na	0.6	0.6	0.6	0.6	0.6	0.5	0.7	0.7	0.7	0.6
pH	7.5	7.9	7.8	7.7	7.7	7.2	7.2	7	6.9	7.1
Buffer pH									6.9	
EC (ms/cm)	0.22	0.18	0.18	0.17	0.18	0.16	0.16	0.16	0.16	0.17
Saturation %P	5	4	4	3	4	10	5	5	9	8
Saturation %Al	0.1	0	0	0	0	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	6	3	3	2	3	3	3	3	3	3
Chloride (ppm)	14	14	11	11	9	12	9	10	13	12
Potential Mineralizable Nitrogen (PMN, ppm)	32	32	30	33	32	35	39	39	38	40
Water Extracted Organic C (ppm)	96	66	64	68	48	56	60	64	76	58
Water Extracted Inorganic N (ppm)	6.5	6.2	5.1	7.7	8.4	8.6	8.8	8.6	8.6	8
Water Extracted Organic N (ppm)	3.5	3.8	4.9	2.3	11.6	21.4	31.2	21.4	11.4	22
Solvita CO2-C (ppm)	50	50	44	52	48	57	69	69	66	72
Reactive C (ppm)	672	676	664	663	635	675	714	714	694	823
Soil Health Index	31	29	30	29	28	31	27	32	32	31
%Microbial Active Carbon (MAC)	52.1	75.8	68	76.9	99.6	102.1	114.5	107.3	86.4	123.4
Organic C:N ratio	27.4	17.4	13.1	29.6	4.1	2.6	1.9	3	6.7	2.6
NRCS Soil Health Calculations	6.3	6	5.5	6.1	5.4	6.5	7.8	7.7	8.5	8
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	64	64	60	66	64	70	78	78	76	80
Water extracted total N	40	10	10	10	20	30	40	30	20	30
Water extracted Soil Nitrate	4	4	3	3	4	7	5	5	5	4
Water extracted Soil Ammonium	3	2	2	5	4	2	4	4	4	4

Field 6: chemical analysis

	Report # C20204-10015									
Parameters	6A-1	6A-2	6A-3	6A-4	6A-5	6B-1	6B-2	6B-3	6B-4	6B-5
Yield (bu/ac)	229.5	229.5	229.5	229.5	229.5	180.3	180.3	180.3	180.3	180.3
Organic Matter (OM, %)	2.9	2.9	3	3.1	2.9	2.7	3	2.7	2.8	2.7
Phopsphorus (Bicarb, ppm)	22	30	34	32	38	27	25	23	17	25
Phopsphorus (Bray, ppm)	43	48	59	59	72	42	37	33	32	37
Potassium (K, ppm)	147	131	137	113	106	93	150	121	147	148
Magnesium (Mg, ppm)	199	189	226	183	200	265	292	277	288	333
Calcium (Ca, ppm)	1010	890	1000	920	970	1140	1240	1240	1220	1360
Sodium (Na, ppm)	12	12	11	12	12	10	13	12	13	13
Sulfur (S, ppm)	12	16	14	14	13	8	10	8	9	8
Zinc (Zn, ppm)	2.3	2.1	2.3	2.5	2.3	2.8	3	2.5	2.7	2.7
Manganese (Mn, ppm)	13	13	15	12	13	17	21	19	19	19
Iron (Fe, ppm)	68	68	71	71	74	79	86	81	80	85
Copper (Cu, ppm)	0.5	0.5	0.6	0.6	0.5	0.8	0.9	0.8	0.8	0.9
Boron (B, ppm)	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.2
Aluminum (Al, ppm)	820	843	948	894	894	634	661	656	690	744
CEC (meq/ 100g)	8.3	7.6	8.5	7.6	8	9.4	10.2	10	10.1	11.2
K/Mg Ratio	0.23	0.21	0.19	0.19	0.16	0.11	0.16	0.13	0.16	0.14
General Fertility Index (GFI)	78	78	70	73	70	63	66	63	65	63
Percent Base Saturation %K	4.5	4.4	4.2	3.8	3.4	2.5	3.8	3.1	3.7	3.4
%Mg	19.9	20.7	22.3	19.9	20.8	23.6	23.8	23	23.8	24.8
%Ca	60.7	58.6	59.1	60.2	60.5	60.9	60.5	61.8	60.4	60.9
%H	14.2	15.5	13.9	15.4	14.7	12.5	11.4	11.6	11.6	10.4
%Na	0.6	0.7	0.6	0.7	0.7	0.5	0.6	0.5	0.6	0.5
pH	6.2	6.4	5.9	5.8	6	6.6	6.3	6.5	6.2	6.5
Buffer pH	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
EC (ms/cm)	0.58	0.8	0.53	0.45	0.32	0.19	0.32	0.35	0.38	0.26
Saturation %P	7	7	8	9	10	9	7	6	6	6
Saturation %Al	0.6	0.5	1.2	1.4	1	0.2	0.4	0.3	0.4	0.3
Nitrate-N (ppm)	56	83	48	38	21	6	21	27	31	15
Chloride (ppm)	12	14	14	12	9	13	18	14	20	15
Potential Mineralizable Nitrogen (PMN, ppm)	35	37	36	40	33	38	47	28	53	42
Water Extracted Organic C (ppm)	48	54	36	24	46	74	68	58	72	72
Water Extracted Inorganic N (ppm)	69.8	157.9	59.1	45.5	20.5	12	22.9	32.7	43.6	15.1
Water Extracted Organic N (ppm)	0.2	12.1	10.9	24.5	9.5		7.1	17.3	1.4	14.9
Solvita CO2-C (ppm)	57	63	60	72	52	66	98	40	134	78
Reactive C (ppm)	708	717	716	722	711	670	746	708	663	671
Soil Health Index	42	42	38	30	37	33	36	33	35	34
%Microbial Active Carbon (MAC)	119.2	116.1	165.8	298.3	113.7	88.8	144.3	69.6	186.1	108.9
Organic C:N ratio	240	4.5	3.3	1	4.8		9.6	3.4	51.4	4.8
NRCS Soil Health Calculations	6.2	6.9	6.4	7.6	5.8	7.3	11.2	4.7	14.3	8.7
Biological Soil Quality	4	4	4	4	4	4	4	3	5	4
Estimated Nitrogen Release (ENR, lb/ac/year)	70	74	72	80	66	76	94	56	106	84
Water extracted total N	70	170	70	70	30	10	30	50	45	30
Water extracted Soil Nitrate	51	92	42	33	19	9	16	24	30	11
Water extracted Soil Ammonium	19	66	17	13	2	3	7	9	14	4

Field 7: chemical analysis

	Report # C20204-10015									
Parameters	7A-1	7A-2	7A-3	7A-4	7A-5	7B-1	7B-2	7B-3	7B-4	7B-5
Yield (bu/ac)	216.2	216.2	216.2	216.2	216.2	213.2	213.2	213.2	213.2	213.2
Organic Matter (OM, %)	3.7	4	4	4	4.4	3.3	3.5	3.3	3.3	3.5
Phopsphorus (Bicarb, ppm)	41	48	45	51	79	53	62	61	66	56
Phopsphorus (Bray, ppm)	85	102	112	118	215	161	165	173	209	144
Potassium (K, ppm)	178	205	152	142	182	147	130	122	118	114
Magnesium (Mg, ppm)	229	221	191	222	297	147	154	168	154	157
Calcium (Ca, ppm)	1700	1770	1600	1640	1720	1160	1230	1380	1310	1150
Sodium (Na, ppm)	13	13	9	11	15	14	15	14	16	15
Sulfur (S, ppm)	7	11	9	9	11	12	16	13	15	13
Zinc (Zn, ppm)	4	4.6	5.5	5	6.7	6.1	6.6	6.6	7.6	6.8
Manganese (Mn, ppm)	32	32	28	31	8	26	29	28	30	29
Iron (Fe, ppm)	73	72	72	69	117	82	84	84	79	80
Copper (Cu, ppm)	4.7	5.4	5.3	5.1	2.2	6.9	7.6	7.7	6.7	6.7
Boron (B, ppm)	0.3	0.3	0.3	0.3	0.4	0.2	0.2	0.2	0.2	0.2
Aluminum (Al, ppm)	783	791	721	778	820	933	904	995	848	969
CEC (meq/ 100g)	12.1	12.4	11.2	11.6	12.8	11	12.6	13.5	10.6	12.2
K/Mg Ratio	0.24	0.28	0.25	0.19	0.19	0.31	0.25	0.22	0.24	0.22
General Fertility Index (GFI)	85	84	81	72	67	83	77	75	83	76
Percent Base Saturation %K	3.8	4.2	3.5	3.1	3.7	3.4	2.6	2.3	2.9	2.4
%Mg	15.8	14.8	14.2	15.9	10.4	11.1	10.2	10.4	12.1	10.7
%Ca	70.3	71.1	71.4	70.5	67.3	52.5	48.8	51.3	61.9	47.1
%H	9.7	9.4	10.5	10.1	9.1	32.4	37.9	35.5	22.5	39.2
%Na	0.5	0.5	0.3	0.4	0.5	0.6	0.5	0.5	0.7	0.5
pH	5.8	5.7	5.8	5.8	6.5	5.1	5.2	5.2	5.3	5.1
Buffer pH	6.9	6.9	6.9	6.9	6.9	6.7	6.6	6.6	6.8	6.6
EC (ms/cm)	0.24	0.54	0.4	0.33	0.24	0.29	0.31	0.28	0.34	0.28
Saturation %P	14	17	20	19	34	22	23	22	32	19
Saturation %Al	0.8	0.9	0.8	0.8	0.3	3.1	2.2	2.3	2.1	2.9
Nitrate-N (ppm)	11	48	32	22	8	17	16	14	20	14
Chloride (ppm)	18	21	13	15	16	19	25	14	20	18
Potential Mineralizable Nitrogen (PMN, ppm)	46	41	40	43	51	38	32	32	35	31
Water Extracted Organic C (ppm)	102	84	68	76	100	126	110	140	152	108
Water Extracted Inorganic N (ppm)	15.7	54.3	27	23.5	9.4	24	22.3	22.7	26.2	17.9
Water Extracted Organic N (ppm)	14.3	5.7	13	16.5	10.6	46	17.7	27.3	23.8	32.1
Solvita CO2-C (ppm)	94	75	72	82	123	55	48	48	57	46
Reactive C (ppm)	830	773	694	766	893	603	619	645	700	664
Soil Health Index	46	46	44	38	36	46	42	40	45	40
%Microbial Active Carbon (MAC)	92.3	88.8	105.3	108.3	123	52.1	43.5	34.1	37.6	42.1
Organic C:N ratio	7.1	14.7	5.2	4.6	9.4	2.7	6.2	5.1	6.4	3.4
NRCS Soil Health Calculations	11.9	8.9	9.1	9.2	14.4	8.3	7.6	8.9	9.6	6
Biological Soil Quality	4	4	4	4	5	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	92	82	80	86	102	76	64	64	70	62
Water extracted total N	30	60	40	40	20	70	40	50	50	50
Water extracted Soil Nitrate	12	50	24	19	6	19	18	18	19	14
Water extracted Soil Ammonium	4	4	3	5	3	5	4	5	7	4

Field 8: chemical analysis

	Report # C20212-10122									
Parameters	8A-1	8A-2	8A-3	8A-4	8A-5	8B-1	8B-2	8B-3	8B-4	8B-5
Yield (bu/ac)	251.7	251.7	251.7	251.7	251.7	196.3	196.3	196.3	196.3	196.3
Organic Matter (OM, %)	6.3	6.8	8.1	6.6	7.1	3.5	3	3.5	3.5	3.6
Phopsphorus (Bicarb, ppm)	27	28	19	37	15	26	11	35	25	43
Phopsphorus (Bray, ppm)	49	59	39	70	30	51	16	63	37	86
Potassium (K, ppm)	185	197	138	166	136	85	76	110	103	103
Magnesium (Mg, ppm)	434	469	433	468	443	456	448	469	451	434
Calcium (Ca, ppm)	2000	2090	2040	2120	2090	2890	3640	3330	3270	3190
Sodium (Na, ppm)	15	16	17	15	17	21	26	20	22	23
Sulfur (S, ppm)	10	10	10	11	11	9	9	9	10	12
Zinc (Zn, ppm)	6.9	7.5	6.4	8.8	5.7	4	2.7	5.3	3.4	7.8
Manganese (Mn, ppm)	4	5	4	4	3	30	29	32	31	29
Iron (Fe, ppm)	94	88	89	91	95	60	57	64	60	64
Copper (Cu, ppm)	2.1	2.2	2.1	2.2	2.3	1.3	1.2	1.5	1.3	1.7
Boron (B, ppm)	0.4	0.5	0.4	0.5	0.4	0.6	0.5	0.7	0.5	0.7
Aluminum (Al, ppm)	904	836	798	893	848	613	530	604	630	564
CEC (meq/ 100g)	21.3	16.1	19	20.9	19.3	18.5	22.2	20.9	20.4	19.9
K/Mg Ratio	0.13	0.13	0.1	0.11	0.09	0.06	0.05	0.07	0.07	0.07
General Fertility Index (GFI)	64	68	61	61	62	51	47	50	56	48
Percent Base Saturation %K	2.2	3.1	1.9	2	1.8	1.2	0.9	1.4	1.3	1.3
%Mg	17	24.3	19	18.6	19.1	20.5	16.8	18.7	18.4	18.2
%Ca	46.9	65	53.7	50.6	54.1	78.1	82	79.8	80.1	80.2
%H	33.6	7.1	25	28.4	24.6	0	0	0	0	0
%Na	0.3	0.4	0.4	0.3	0.4	0.5	0.5	0.4	0.5	0.5
pH	5.8	5.9	5.7	5.8	5.8	7.7	8	7.8	7.9	7.8
Buffer pH	6.4	6.9	6.6	6.5	6.6	0				
EC (ms/cm)	0.21			0.24	0.23	0.22	0.24	0.24	0.23	0.25
Saturation %P	7	9	6	10	4	4	1	5	3	7
Saturation %Al	0.5	0.5	0.6	0.5	0.5	0	0	0	0	0
Nitrate-N (ppm)	4			7	5	2	1	2	1	2
Chloride (ppm)	10			12	13	16	11	13	13	15
Potential Mineralizable Nitrogen (PMN, ppm)	47			48	50	39	33	38	37	40
Water Extracted Organic C (ppm)	232			184	216	104	120	128	136	118
Water Extracted Inorganic N (ppm)	18.1			18.7	16.8	10.2	9.2	10	9	11
Water Extracted Organic N (ppm)	21.9			31.3	33.2	29.8	20.8	10	11	29
Solvita CO2-C (ppm)	98			102	113	69	52	66	63	72
Reactive C (ppm)	845				846	715	649	730	746	750
Soil Health Index	34	36	32	32	33	26	24	26	29	25
%Microbial Active Carbon (MAC)	42.3			55.4	52.3	66.1	43.6	51.3	46.1	60.7
Organic C:N ratio	10.6			5.9	6.5	3.5	5.8	12.8	12.4	4.1
NRCS Soil Health Calculations	14.3			15.2	16.8	8.2	8.5	8.9	8.7	8.6
Biological Soil Quality	4			4	5	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	94			96	100	78	66	76	74	80
Water extracted total N	40			50	50	40	30	20	20	40
Water extracted Soil Nitrate	12			14	11	7	6	7	6	8
Water extracted Soil Ammonium	6			5	6	3	3	3	3	4

Field 9: chemical analysis

	Report # C20212-10122									
Parameters	9A-1	9A-2	9A-3	9A-4	9A-5	9B-1	9B-2	9B-3	9B-4	9B-5
Yield (bu/ac)	176.0	176.0	176.0	176.0	176.0	183.6	183.6	183.6	183.6	183.6
Organic Matter (OM, %)	3.6	3.4	3.4	3.4	3.2	4.2	4.4	4.3	4.3	4.3
Phopsphorus (Bicarb, ppm)	40	50	49	52	37	55	57	51	57	47
Phopsphorus (Bray, ppm)	91	112	97	105	84	137	132	137	132	126
Potassium (K, ppm)	112	137	140	156	129	160	167	145	141	134
Magnesium (Mg, ppm)	206	203	190	202	199	284	270	248	260	260
Calcium (Ca, ppm)	3290	3420	3310	3410	3590	2510	2690	2510	258	2730
Sodium (Na, ppm)	15	16	14	15	18	18	17	14	27	16
Sulfur (S, ppm)	6	7	9	7	7	7	7	7	7	7
Zinc (Zn, ppm)	10.7	12.9	13.2	13.6	11.2	15.9	15.8	15.8	15.7	14.3
Manganese (Mn, ppm)	117	119	112	122	119	75	74	70	71	69
Iron (Fe, ppm)	79	81	77	78	78	104	105	104	106	100
Copper (Cu, ppm)	3.4	4	4	4.2	3.7	5.3	5.2	5.3	5	4.9
Boron (B, ppm)	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
Aluminum (Al, ppm)	631	650	586	625	638	774	729	715	735	683
CEC (meq/ 100g)	18.5	19.2	18.5	19.2	20	16.6	17.4	17.3	17.1	17
K/Mg Ratio	0.17	0.2	0.22	0.24	0.2	0.17	0.19	0.18	0.17	0.16
General Fertility Index (GFI)	62	66	67	68	67	66	68	73	68	64
Percent Base Saturation %K	1.6	1.8	1.9	2.1	1.7	2.5	2.5	2.2	2.1	2
%Mg	9.3	8.8	8.5	8.8	8.3	14.3	13	12	12.7	12.7
%Ca	88.9	89.1	89.5	88.9	89.8	75.7	77.4	72.6	75.6	80.2
%H	0	0	0	0	0	7.1	6.7	12.9	8.9	4.6
%Na	0.4	0.4	0.3	0.3	0.4	0.5	0.4	0.4	0.7	0.4
pH	8	8	8	7.9	8.1	6.9	6.8	7	7.1	7.2
Buffer pH						6.9	6.9			
EC (ms/cm)	0	0.22	0.28	0.24	0.23	0.59	0	0.68	0.49	0.41
Saturation %P	7	8	7	8	6	23	11	24	23	10
Saturation %Al	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)		2	8	4	2	55		66	40	29
Chloride (ppm)		7	11	7	8	10		9	7	8
Potential Mineralizable Nitrogen (PMN, ppm)		23	30	20	20	41		37	35	37
Water Extracted Organic C (ppm)		94	110	86	96	102		84	76	90
Water Extracted Inorganic N (ppm)		12.4	17.4	14.7	11.7	70.4		74.4	53	36.1
Water Extracted Organic N (ppm)		17.6	22.6	25.3	28.3	29.6		25.6	37	23.9
Solvita CO2-C (ppm)		30	44	24	24	75		63	57	63
Reactive C (ppm)		716	673	700	725			860	851	835
Soil Health Index	33	35	36	37	36	35		38	36	34
%Microbial Active Carbon (MAC)		32.2	39.5	28.1	25.2	73.1		74.6	75.3	69.7
Organic C:N ratio		5.3	4.9	3.4	3.4	3.4		3.3	2.1	3.8
NRCS Soil Health Calculations		5.7	5.7	3.5	3.7	8.8		7.4	6.9	7.4
Biological Soil Quality		3	4	3	3	4		4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)		46	60	40	40	82		74	70	74
Water extracted total N		30	40	40	40	100		100	90	60
Water extracted Soil Nitrate		8	14	11	8	64		69	50	32
Water extracted Soil Ammonium		4	3	4	4	6		5	3	4

Field 10: chemical analysis

	Report # C20212-10122									
Parameters	10A-1	10A-2	10A-3	10A-4	10A-5	10B-1	10B-2	10B-3	10B-4	10B-5
Yield (bu/ac)	181.6	181.6	181.6	181.6	181.6	202.5	202.5	202.5	202.5	202.5
Organic Matter (OM, %)	5.6	5.8	5.7	5.8	5.8	6.8	6.7	6.5	6.4	6.3
Phopsphorus (Bicarb, ppm)	43	43	28	35	35	56	51	57	62	62
Phopsphorus (Bray, ppm)	73	83	56	56	71	144	135	140	152	145
Potassium (K, ppm)	122	142	129	123	146	180	191	196	174	168
Magnesium (Mg, ppm)	306	301	316	280	317	182	186	175	173	185
Calcium (Ca, ppm)	3320	3000	3400	300	3450	3700	4330	3960	4040	4070
Sodium (Na, ppm)	14	13	15	12	17	14	15	15	12	14
Sulfur (S, ppm)	10	12	10	10	14	21	16	15	36	23
Zinc (Zn, ppm)	4.2	4.1	3.6	3.6	5.2	12.9	13.6	12.2	13.7	13
Manganese (Mn, ppm)	16	14	15	14	13	21	21	23	21	22
Iron (Fe, ppm)	98	83	95	84	89	94	101	95	96	93
Copper (Cu, ppm)	4.9	4.4	5	4.4	5	4.9	5.7	4.7	5.1	5.1
Boron (B, ppm)	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.6	0.6	0.6
Aluminum (Al, ppm)	853	821	848	789	827	495	537	486	492	471
CEC (meq/ 100g)	19.5	18.8	20	17.7	20.3	20.5	23.7	21.8	22.1	22.4
K/Mg Ratio	0.12	0.14	0.13	0.14	0.14	0.3	0.32	0.34	0.31	0.28
General Fertility Index (GFI)	60	68	58	58	63	65	64	65	62	62
Percent Base Saturation %K	1.6	1.9	1.7	1.8	1.8	2.2	2.1	2.3	2	1.9
%Mg	13.1	13.3	13.2	13.2	13	7.4	6.5	6.7	6.5	6.9
%Ca	85.2	79.8	85	84.9	85	90.2	91.2	90.8	91.3	91
%H	0	4.6	0	0	0	0	0	0	0	0
%Na	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.3
pH	7.6	7.2	7.8	7.7	7.7	7.8	7.8	7.6	7.6	7.7
Buffer pH										
EC (ms/cm)		0.45	0.24	0.32	0.37	0.35	0.33	0.6		0.36
Saturation %P	6	7	4	4	5	10	9	10	11	10
Saturation %Al	0	0.1	0	0	0	0	0	0	0	0
Nitrate-N (ppm)		30	2	14	16	8	6	44		7
Chloride (ppm)		13	9	12	9	12	10	12		10
Potential Mineralizable Nitrogen (PMN, ppm)	0	42	35	43	39	39	40	36		36
Water Extracted Organic C (ppm)		150	164	152	178	184	210	186		172
Water Extracted Inorganic N (ppm)		58	12.1	26.1	29.7	19.5	14.9	70.5		15.5
Water Extracted Organic N (ppm)		32	27.9	23.9	40.3	20.5	25.1	29.5		24.5
Solvita CO2-C (ppm)		78	57	82	69	69	72	60		60
Reactive C (ppm)		864	894	909	905	911	906	892		858
Soil Health Index	31	36	31	31	33	35	35	35	34	34
%Microbial Active Carbon (MAC)		52.3	34.9	54.1	38.6	37.3	34.1	32.1		34.7
Organic C:N ratio		4.7	5.9	6.4	4.4	9	8.4	6.3		7
NRCS Soil Health Calculations		9.7	10.2	12.1	9.1	10.8	11.8	10.8		10.1
Biological Soil Quality		4	4	4	4	4	4	4		4
Estimated Nitrogen Release (ENR, lb/ac/year)		84	70	86	78	78	80	72		72
Water extracted total N		90	40	50	70	40	40	100		40
Water extracted Soil Nitrate		38	7	18	23	13	10	51		12
Water extracted Soil Ammonium		20	5	8	7	7	5	20		4

Field 11: chemical analysis

	Report # C20212-10122									
Parameters	11A-1	11A-2	11A-3	11A-4	11A-5	11B-1	11B-2	11B-3	11B-4	11B-5
Yield (bu/ac)	166.5	166.5	166.5	166.5	166.5	205.2	205.2	205.2	205.2	205.2
Organic Matter (OM, %)	4.2	4.3	3.9	4	3.7	4.3	4.4	4.2	4.1	4.6
Phopsphorus (Bicarb, ppm)	20	32	14	17	11	26	30	19	28	31
Phopsphorus (Bray, ppm)	38	50	19	24	15	52	55	38	42	55
Potassium (K, ppm)	129	157	118	113	100	132	128	113	122	128
Magnesium (Mg, ppm)	291	333	285	315	311	431	387	378	399	399
Calcium (Ca, ppm)	2950	3000	2630	2580	2880	2720	2360	2460	2670	2650
Sodium (Na, ppm)	15	16	15	15	16	16	15	18	18	17
Sulfur (S, ppm)	10	11	8	12	7	9	10	10	10	9
Zinc (Zn, ppm)	3.6	3.6	2.8	2.9	3	3	3	3	2.8	3.2
Manganese (Mn, ppm)	64	73	60	67	67	28	26	26	31	35
Iron (Fe, ppm)	67	64	61	60	60	81	75	69	70	74
Copper (Cu, ppm)	2.3	2.6	2.3	2.3	2.2	2.8	2.7	2.7	2.8	2.7
Boron (B, ppm)	0.5	0.6	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Aluminum (Al, ppm)	660	693	703	719	720	858	832	828	841	829
CEC (meq/ 100g)	17.5	18.2	15.9	15.8	17.3	20.2	16.6	17.4	17.9	19
K/Mg Ratio	0.14	0.14	0.13	0.11	0.1	0.1	0.1	0.09	0.1	0.1
General Fertility Index (GFI)	56	59	50	49	48	69	60	61	55	69
Percent Base Saturation %K	1.9	2.2	1.9	1.8	1.5	1.7	2	1.7	1.8	1.7
%Mg	13.8	15.2	15	16.6	15	17.8	19.5	18.2	18.6	17.5
%Ca	84.1	82.4	82.9	81.4	83.3	67.4	71.2	70.9	74.7	67.5
%H	0	0	0	0	0	12.8	7	8.9	4.5	12.8
%Na	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.5	0.4	0.4
pH	7.6	7.7	7.6	7.6	7.5	7	6.9	7.1	7.2	7
Buffer pH							6.9			
EC (ms/cm)	0.39	0.3	0.21	0.29	0.32	0.23				0.24
Saturation %P	3	4	1	2	1	8	9	6	6	9
Saturation %Al	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	23	11	2	11	17	4				6
Chloride (ppm)	11	18	10	11	13	10				10
Potential Mineralizable Nitrogen (PMN, ppm)	40	40	41	39	34	42				43
Water Extracted Organic C (ppm)	110	124	162	114	132	192				164
Water Extracted Inorganic N (ppm)	34.7	16.2	9.7	18.9	29.1	14.1				15.4
Water Extracted Organic N (ppm)	25.3	13.8	20.3	21.1	30.9	25.9				14.6
Solvita CO2-C (ppm)	72	72	75	69	55	78				82
Reactive C (ppm)	807	817	783	801	740	823				888
Soil Health Index	30	31	27	26	25	36	32	32	29	36
%Microbial Active Carbon (MAC)	65.1	57.7	46	60.3	41.3	40.8				50.2
Organic C:N ratio	4.3	9	8	5.4	4.3	7.4				11.2
NRCS Soil Health Calculations	8.5	9.8	11.1	10.1	7.1	12.4				11.3
Biological Soil Quality	4	4	4	4	4	4				4
Estimated Nitrogen Release (ENR, lb/ac/year)	80	80	82	78	68	84				86
Water extracted total N	60	30	30	30	60	40				30
Water extracted Soil Nitrate	30	13	5	14	24	9				12
Water extracted Soil Ammonium	5	3	5	5	5	5				3

Field 12: chemical analysis

	Report # C20204-10015									
Parameters	12A-1	12A-2	12A-3	12A-4	12A-5	12B-1	12B-2	12B-3	12B-4	12B-5
Yield (bu/ac)	222.7	222.7	222.7	222.7	222.7	251.0	251.0	251.0	251.0	251.0
Organic Matter (OM, %)	4	3.9	3.9	4	4	3.2	3.3	3.3	3.2	3.2
Phopsphorus (Bicarb, ppm)	73	75	85	81	75	131	135	124	126	143
Phopsphorus (Bray, ppm)	207	215	235	232	202	377	389	380	392	416
Potassium (K, ppm)	221	225	253	251	128	243	268	260	266	275
Magnesium (Mg, ppm)	243	281	288	292	195	191	207	196	189	202
Calcium (Ca, ppm)	2050	2450	2290	2450	1500	1610	1670	1560	1560	1530
Sodium (Na, ppm)	19	17	17	22	17	14	19	17	18	16
Sulfur (S, ppm)	10	13	11	14	10	13	13	12	13	16
Zinc (Zn, ppm)	13.5	15.7	16.4	15.7	12.2	17.9	18.2	18.7	18.8	18.9
Manganese (Mn, ppm)	43	44	50	46	44	20	20	20	18	18
Iron (Fe, ppm)	108	119	114	119	106	144	159	153	147	146
Copper (Cu, ppm)	5.3	5.9	6.4	6	4.6	4.5	4.3	4.4	4.4	4.5
Boron (B, ppm)	0.4	0.6	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3
Aluminum (Al, ppm)	781	806	856	856	722	790	864	803	801	862
CEC (meq/ 100g)	14.8	16.7	16	16.2	10.7	11.5	12	11.4	11.3	11.3
K/Mg Ratio	0.28	0.24	0.27	0.26	0.2	0.39	0.4	0.41	0.43	0.42
General Fertility Index (GFI)	80	75	79	72	72	73	74	73	73	70
Percent Base Saturation %K	3.8	3.4	4.1	4	3.1	5.4	5.7	5.9	6	6.2
%Mg	13.7	14	15	15.1	15.2	13.8	14.3	14.4	13.9	14.9
%Ca	69.1	73.2	71.6	75.8	70.1	70	69.5	68.7	68.9	67.8
%H	12.9	8.9	8.9	4.6	11	10.2	9.8	10.4	10.4	10.4
%Na	0.6	0.4	0.5	0.6	0.7	0.5	0.7	0.7	0.7	0.6
pH	7	7.1	7.1	7.2	6.8	6.3	6.4	6.4	6.3	6.2
Buffer pH					6.9	6.9	6.9	6.9	6.9	6.9
EC (ms/cm)	0.21	0.23	0.21	0.24	0.18	0.22	0.21	0.21	0.22	0.22
Saturation %P	34	34	35	35	36	61	58	61	63	62
Saturation %Al	0.1	0.1	0.1	0.1	0.2	0.4	0.3	0.3	0.4	0.5
Nitrate-N (ppm)	3	2	2	3	2	4	3	4	4	3
Chloride (ppm)	10	11	13	11	14	22	9	18	14	10
Potential Mineralizable Nitrogen (PMN, ppm)	38	39	41	39	37	36	34	33	34	37
Water Extracted Organic C (ppm)	108	116	164	120	140	96	122	114	110	102
Water Extracted Inorganic N (ppm)	9.8	11.3	10.6	15.9	16.3	11.7	9.8	11.8	10.5	9.1
Water Extracted Organic N (ppm)	30.2	18.7	9.4	24.1	13.7	18.3	30.2	38.2	19.5	20.9
Solvita CO2-C (ppm)	66	69	75	69	63	60	55	52	55	63
Reactive C (ppm)	796	832	834	790	815	747	736	738	724	735
Soil Health Index	44	41	43	40	39	40	40	39	39	30
%Microbial Active Carbon (MAC)		59.2	45.5	57.3	44.8	62.2	44.7	45.9	49.5	61.5
Organic C:N ratio	3.6	6.2	17.4	5	10.2	5.2	4	3	5.6	4.9
NRCS Soil Health Calculations		9.9	10	10.5	9	8.8	7	6.8	8.5	7.5
Biological Soil Quality	4	4	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	76	78	82	78	74	72	68	66	68	74
Water extracted total N	40	30	20	40	30	30	40	50	30	30
Water extracted Soil Nitrate	7	8	7	13	13	9	7	10	8	6
Water extracted Soil Ammonium	3	3	4	3	3	3	3	2	3	3

Field 13: chemical analysis

	Report # C20226-10175									
Parameters	13A-1	13A-2	13A-3	13A-4	13A-5	13B-1	13B-2	13B-3	13B-4	13B-5
Yield (bu/ac)	206.6	206.6	206.6	206.6	206.6	137.4	137.4	137.4	137.4	137.4
Organic Matter (OM, %)	5.1	5.1	5.5	5.5	5.4	4	3.9	4	3.8	3.7
Phopsphorus (Bicarb, ppm)	27	36	34	32	39	34	33	39	23	24
Phopsphorus (Bray, ppm)	57	62	71	59	69	67	60	89	47	46
Potassium (K, ppm)	162	198	192	158	173	149	148	146	130	142
Magnesium (Mg, ppm)	321	328	338	308	307	450	465	472	471	465
Calcium (Ca, ppm)	2390	2430	2370	2250	2280	2620	2360	2340	2310	2410
Sodium (Na, ppm)	19	21	19	19	19	26	30	23	21	20
Sulfur (S, ppm)	7	8	8	8	7	13	10	9	8	8
Zinc (Zn, ppm)	5.1	4.5	4.6	3.9	4.9	5.8	6	8.3	4.5	2.8
Manganese (Mn, ppm)	5	6	7	8	6	18	19	18	16	17
Iron (Fe, ppm)	137	142	144	135	133	83	87	86	82	88
Copper (Cu, ppm)	2.4	2.6	2.6	2.4	2.5	1.3	1.3	1.3	1.2	1.2
Boron (B, ppm)	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.5
Aluminum (Al, ppm)	1010	1045	1112	980	982	837	921	914	904	942
CEC (meq/ 100g)	19.9	23.8	18.8	19.1	20.5	19	17.3	17.3	18.2	17.5
K/Mg Ratio	0.16	0.18	0.17	0.16	0.18	0.1	0.1	0.1	0.08	0.1
General Fertility Index (GFI)	69	68	73	69	71	65	63	59	69	65
Percent Base Saturation %K	2.1	2.1	2.6	2.1	2.2	2	2.2	2.2	1.8	2.1
%Mg	13.5	11.5	15	13.5	12.5	19.7	22.4	22.8	21.5	22.1
%Ca	60.1	51	63	59	55.7	68.9	68.1	67.8	63.4	68.8
%H	24	35.1	18.9	25	29.2	8.8	6.6	6.7	12.8	6.6
%Na	0.4	0.4	0.4	0.4	0.4	0.6	0.8	0.6	0.5	0.5
pH	5.9	5.7	5.8	6.5	5.8	7.1	6.9	6.8	7	6.9
Buffer pH	6.6	6.3	6.7	6.6	6.5		6.9	6.9		6.9
EC (ms/cm)	0.22	0.27	0.24	0.2	0.23	0.27	0.23	0.24	0.2	0.19
Saturation %P	7	8	8	8	9	10	8	12	7	6
Saturation %Al	0.05	0.6	0.7	0.2	0.6	0.1	0.1	0.1	0.1	0.1
Nitrate-N (ppm)	6	11	7	2	7	6	4	6	2	1
Chloride (ppm)	10	11	13	9	10	12	13	77	12	13
Potential Mineralizable Nitrogen (PMN, ppm)	36	28	43	37	39	47	45	43	41	45
Water Extracted Organic C (ppm)	226	262	252	242	210	266	238	230	206	258
Water Extracted Inorganic N (ppm)	18.8	21.1	18.4	12.6	21.1	15	20.1	18.1	12	14.8
Water Extracted Organic N (ppm)	21.2	18.9	31.6	17.4	28.9	25	29.9	21.9	18	15.2
Solvita CO2-C (ppm)	60	40	82	63	69	98	90	82	75	90
Reactive C (ppm)	822	826	826	891	822	686	722	710	636	673
Soil Health Index	37	36	39	37	38	34	33	31	36	34
%Microbial Active Carbon (MAC)	26.4	15.2	32.7	25.9	32.7	36.9	37.9	35.8	36.2	35
Organic C:N ratio	10.7	13.9	8	13.9	7.3	10.6	8	10.5	11.4	17
NRCS Soil Health Calculations	10.4	8.5	13.9	10.4	11.9	15	14.4	12.7	11.3	13.1
Biological Soil Quality	4	3	4	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	72	56	86	74	78	94	90	86	82	90
Water extracted total N	40	40	50	30	50	40	50	40	30	30
Water extracted Soil Nitrate	14	17	13	8	17	10	14	14	6	8
Water extracted Soil Ammonium	5	4	5	4	4	5	6	4	6	7

Field 14: chemical analysis

	Report # C20212-10122									
Parameters	14A-1	14A-2	14A-3	14A-4	14A-5	14B-1	14B-2	14B-3	14B-4	14B-5
Yield (bu/ac)	145.6	145.6	145.6	145.6	145.6	238.0	238.0	238.0	238.0	238.0
Organic Matter (OM, %)	3.8	3.9	3.6	3.7	3.6	3.2	3.2	3.3	3.4	3.3
Phopsphorus (Bicarb, ppm)	46	48	39	50	48	29	29	31	28	27
Phopsphorus (Bray, ppm)	116	109	87	109	114	47	58	58	51	56
Potassium (K, ppm)	101	101	59	69	76	105	101	117	136	148
Magnesium (Mg, ppm)	61	46	25	28	29	109	90	99	108	114
Calcium (Ca, ppm)	380	300	260	150	260	840	800	800	870	850
Sodium (Na, ppm)	14	12	10	16	14	12	12	13	17	14
Sulfur (S, ppm)	21	20	25	23	20	14	15	12	13	12
Zinc (Zn, ppm)	8.1	7.5	4.4	6.2	6.5	5.9	8.6	9.9	7.8	9.1
Manganese (Mn, ppm)	8	7	4	6	6	12	14	13	12	12
Iron (Fe, ppm)	80	77	76	78	80	62	65	66	65	64
Copper (Cu, ppm)	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Boron (B, ppm)	0.2	0.2	0.2	0.2	0.1	0.4	0.4	0.4	0.4	0.4
Aluminum (Al, ppm)	1544	1515	1399	1401	1464	1093	1114	1102	1083	1094
CEC (meq/ 100g)	13.5	9.4	11.3	12	9	7.8	7.5	6.4	8.1	6.8
K/Mg Ratio	0.5	0.68	0.72	0.79	0.81	0.29	0.35	0.36	0.38	0.4
General Fertility Index (GFI)	50	51	41	42	46	83	79	84	83	76
Percent Base Saturation %K	1.9	2.8	1.3	1.5	2.2	3.4	3.5	4.7	4.3	5.6
%Mg	3.8	4.1	1.8	1.9	2.7	11.6	10.1	12.9	11.2	13.9
%Ca	14.1	16	11.5	6.2	14.5	53.7	53.7	62.8	54	62.2
%H	79.8	76.6	84.9	89.8	80	30.5	32.1	18.7	29.6	17.4
%Na	0.5	0.6	0.4	0.6	0.7	0.7	0.7	0.9	0.9	0.9
pH	5.5	5.2	4.9	5.1	4.8	5.6	5.6	6.1	6.3	6.2
Buffer pH	6.1	6.4	6.2	6.1	6.4	6.8	6.8	6.9	6.8	6.9
EC (ms/cm)	0.19	0.18	0.2	0.19	0.2	0.45	0.33	0.82	0.19	0.17
Saturation %P	10	9	8	10	10	5	7	7	6	6
Saturation %Al	2.2	5	6.1	4.2	9.4	2.3	2.5	1.3	0.8	1.1
Nitrate-N (ppm)	1	1	1	1	4	38	21	88	4	2
Chloride (ppm)	6	7	5	5	7	8	7	10	8	8
Potential Mineralizable Nitrogen (PMN, ppm)	31	31	23	30	34	33	33	38	39	37
Water Extracted Organic C (ppm)	22	88	104	96	102	64	72	74	86	88
Water Extracted Inorganic N (ppm)	12	11.8	11.7	12	43.7	40.8	23.8	14.7	8.9	8.1
Water Extracted Organic N (ppm)			8.3			19.2	16.2	5.3	11.1	11.9
Solvita CO2-C (ppm)	46	46	29	44	55	52	52	66	69	63
Reactive C (ppm)	819	852	805	824	841	836	855	833	862	822
Soil Health Index	27	28	22	23	25	44	43	46	45	41
%Microbial Active Carbon (MAC)	206.8	51.7	27.9	45.3	53.4	81.7	72.6	88.8	79.9	71.3
Organic C:N ratio			12.5			3.3	4.4	14	7.7	7.4
NRCS Soil Health Calculations	4.8	5.4	4.8	5.3	6.2	6.4	6.1	7.8	8.8	8.3
Biological Soil Quality	4	4	3	4	4	4	4	4	4	4
Estimated Nitrogen Release (ENR, lb/ac/year)	62	62	46	60	68	66	66	76	78	74
Water extracted total N	10	10	20	10	20	60	40	20	20	20
Water extracted Soil Nitrate	10	10	10	10	40	37	20	11	5	3
Water extracted Soil Ammonium	2	2	2	2	4	4	4	4	4	5

A&L Biologicals

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Soil Health Analysis of Corn Fields- preliminary report

Client name	Date
St.Clair Region Soil and Crop Improvement Association 2018-2020 Tier 2 Project	November 28, 2018

The **objective** of this work was to compare A&L laboratories' new soil health analysis and how it corelates to yield and plant performance.

Methods

A&L received 170 corn roots, with their respective rot ball soil, for analysis. The samples were collected by OMAFRA, Ridgetown office from seventeen corn field across South-Western Ontario. Before sample collection, NDVI maps of each field were created and used to select a healthy and an stressed area within each field. Using GPS guided sampling, 5 corn plants, with their respective soil attached to the root ball, were collected per area for a total of 10 plants per field. The roots with their attached soil were separated, code labelled, packaged individually and sent to A&L (Table 1).

Table 1. List of samples received for analysis

Field	Samples	Samples
18-1	18-1A-1 to 5	18-1B-1 to 5
18-2	18-2A-1 to 5	18-2B-1 to 5
18-3	18-3A-1 to 5	18-3B-1 to 5
18-4	18-4A-1 to 5	18-4B-1 to 5
18-5	18-5A-1 to 5	18-5B-1 to 5
18-6	18-6A-1 to 5	18-6B-1 to 5
18-8	18-8A-1 to 5	18-8B-1 to 5
18-9	18-9A-1 to 5	18-9B-1 to 5
18-10	18-10A-1 to 5	18-10B-1 to 5
18-11	18-11A-1 to 5	18-11B-1 to 5
18-12	18-12A-1 to 5	18-12B-1 to 5
18-13	18-13A-1 to 5	18-13B-1 to 5
18-14	18-14A-1 to 5	18-14B-1 to 5
18-15	18-15A-1 to 5	18-15B-1 to 5
18-16	18-16A-1 to 5	18-16B-1 to 5
18-17	18-17A-1 to 5	18-17B-1 to 5
18-18	18-18A-1 to 5	18-18B-1 to 5

Upon receiving the samples, soil was separated from the roots and sent for Soil Health analysis. A total of 170 soil samples were analysed.

The roots from 11 fields (18-1A-1B, 18-2A-2B, 18-3A-3B, 18-4A-4B, 18-5A-5B, 18-6A-6B, 18-8A-8B, 18-9A-9B, 18-10A-10B, 18-17A-17B, and 18-18A-18B) were then washed with tap water and chopped. A portion was weighted and stored at -20°C for future DNA extraction. The DNA was used to compare the root' microbial communities of plants from the two areas within each field.

Soil Health Analysis: A&L's newly developed soil health test (VitTellus) was used to determine the different chemical and physical parameters of the soil, resulting in a Soil Health Index. This index ranges from 0 to 60 and highly correlates to yield and the presence of a combination of disease suppressive and bio-stimulating organisms in the plant microbiome (root zone). The parameters measured by this test included: Organic matter, pH, BpH, P, K, Mg, Ca, Na, S, B, Cu, Mn, Fe, Zn, AL, CEC, %saturation of cations, K: Mg, EC, %P, %AL, Solvita CO2-C, PMN, Active C, NO_3-N and NH_4-N.

Analysis of the microbial communities: To compare the microbial populations associated with the different samples, we used bacterial and fungal TRFLP analysis of DNA extracted from roots. TRFLP is a fingerprinting technique for monitoring composition of microbial communities and it can be used to track spatial and temporal shifts in microbial populations.

Briefly, a conserved region of DNA extracted from roots (16S rRNA gene for bacteria) was amplified with fluorescently labeled primers. The fluorescent PCR products were then digested with a restriction enzyme. The size and quantity of the fragments were determined using capillary electrophoresis. The banding pattern obtained provided a fingerprint of the microbial community. The relationship of such fingerprints to one another was identified using a multivariate statistical technique called Principle Component Analysis (PCA). Principle Components (PC) are statistical values generated to best explain the variation in a set of samples. TRFLP data was transformed into binary data (is a specific peak present (1) or not (0)) before performing PCA. PCA analysis clustered the data based on similarity of peak presence; 95% confidence intervals were automatically drawn around each treatment group. Groups that do not overlap are consider statistically different in their microbial community.

Results

A summary of the soil chemical analysis of fields 18-4, 18-5, and 18-6 is presented in Table 2. In this Table the average per area (A or B) within each field is presented. Full chemical analysis per sample can be found in the appendix.

Table 2. Soil Analysis of Field 18-4, 18-5, and 18-6.

Parameters	4A	4B	5A	5B	6A	6B
CEC, meq/ 100g	18	14	13.0	14.6	19	18
K/Mg Ratio	0.17	0.14	0.3	0.3	0.18	0.17
GFI	**71**	**64**	**90**	**87**	**52**	**60**
%K	2.6	2.6	3.6	2.9	1.3	1.7
%Mg	15.3	18.6	11.2	10.7	7.3	9.7
%Ca	63.2	68.9	55.8	56.7	35.7	35.7
%H	18.5	9.5	29.0	29.3	55.3	52.6
%Na	0.4	0.4	0.5	0.5	0.3	0.3
pH	6.4	7.0	5.8	5.9	5.1	5.1
Buffer pH	6.7	6.9	6.7	6.6	6.1	6.2
EC, ms/cm	0.2	0.2	0.2	0.2	0.3	0.3
Saturation %P	5.0	7.8	18.0	13.6	3.8	6.2
Saturation %Al	0.2	0.1	0.8	0.6	2.4	2.2
Nitrate-N, ppm	4.2	2.0	4.2	3.8	7.8	10.6
Chloride, ppm	12.8	15.4	26.4	26.6	18.2	20.2
PMN, ppm	52.4	59.0	56.2	54.0	49.0	57.2
Organic C, ppm	248	166	219	203	188	231
Inorganic N, ppm	8.3	4.3	8.8	6.8	23.8	35.1
Organic N, ppm	53.7	33.7	59.2	65.2	30.2	40.9
Solvita CO2-C,ppm	157	237	197	193	111	198
Reactive C, ppm	844	842	864	843	659	650
Soil Health Index	**37**	**34**	**48**	**47**	**31**	**40**
%MAC	61.0	144.5	89.8	98.4	59.8	86.9
Organic C:N ratio	4.6	5.3	3.9	3.9	6.6	7.1
NRCS Soil Health Calculations	64.4	27.1	23.2	23.3	15.2	23.4
Biological Quality Result	4.8	5.4	5.1	5.1	4.8	5.2
Organic Matter%	4.1	3.7	3.7	3.5	3.6	3.7
Phopsphorus Bicarb ppm	18.4	20.4	46.0	40.0	23.2	30.2
Phopsphorus Bray ppm	31.6	34.4	108.0	86.0	35.0	52.6
Potassium	176.0	138.2	178.4	165.2	99.6	119.6
Magnesium	326.0	306.6	173.8	187.2	166.2	212.2
Calcium	2244	1890	1446	1656	1354	1300
Sodium	16.8	12.0	13.2	16.8	13.8	11.4
Sulfur	10.6	8.8	12.0	11.6	21.2	12.6
Zinc	3.0	3.3	4.0	3.6	3.3	3.8
Manganese ppm	5.0	23.8	8.0	8.2	10.6	7.0
Iron ppm	106.2	72.8	90.6	95.6	102.2	110.8
Copper	3.7	2.3	2.4	2.5	1.3	1.3
Boron	0.8	0.8	0.6	0.6	0.2	0.1
Aluminum	824	566	775	807	1127	1079
ENR(Estimated N release)	105	118	112	108	98	114
Water extracted total N	62	38	68	72	54	78
Water extracted Soil Nitrate	5	2	4	4	10	14
Water extracted Soil Ammonium	3	2	5	2	14	21

Field 18-4: the soil from this field had good levels of microbial activity. Soils collected from the site A had a better General Fertility Index (GFI) and Soil Health Index (SHI) than the soils collected from site B (GFI 71 vs 64, SHI 37 vs 34). A GFI of 71 is considered good and a SHI of 37 is considered good to high, while a GFI of 64 is considered medium and a SHI of 34 is considered medium to good. Soil from site A had organic carbon than site B (248 ppm vs 166 ppm), and a slightly better K to Mg ratio of 0.17 vs 0.14. Our research has shown that a K/Mg ratio between 0.25 and 0.35 is ideal for crop productivity. Soils from site A had double the amount of nitrate, and organic and inorganic nitrogen than soils from site B.

Microbial communities

The composition and relative abundance of the microbial communities of roots from the two different sites were analysed using TRFLP. Results were summarized in two different ways. Figure 1A shows each bacterial TRFLP result as a vector. Each vector represents the bacterial community of one plant (named 1- 5). The closer the vectors are to each other, the more similar are the populations they represent. The root bacterial communities from site A clustered together in the top right quadrant, while the communities from site B clustered in the bottom right quadrant, suggesting that the root microbial communities from those sites were different. To visualize if there were any statistically significant differences between the communities from site A and B, we summarized our results as single data points and plotted them two dimensionally (Figure 1B). The degree of separation between samples indicates the extent of similarities or differences. The further the dots are separated, the greater the difference. The closer they are, the more similar the population. Confidence circles (95%) that do not overlap are considered significantly different. This analysis confirmed that the root' bacterial populations of site A and site B were somehow different although the differences were not statistically significant.

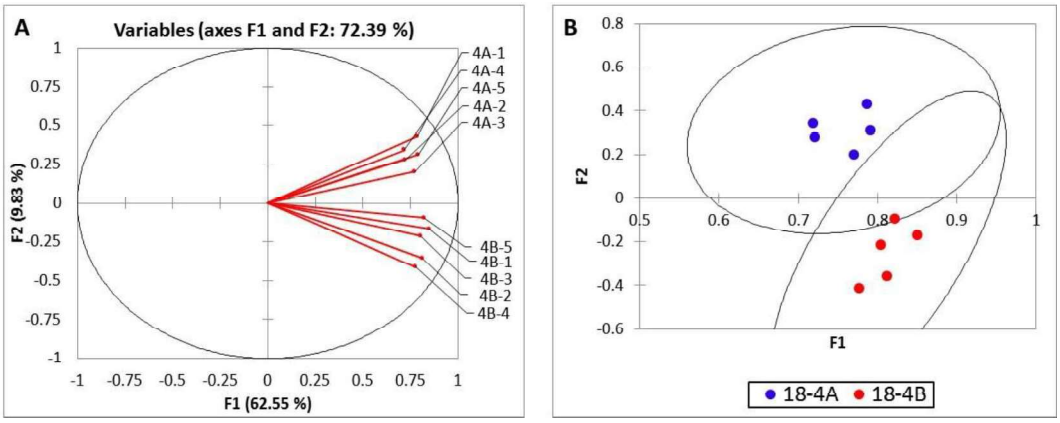

Figure 1. Statistical analysis of TRFLP results for the bacterial communities in corn roots of 18-4A and 18-4B. Bacterial communities are represented as vectors (A) and as points(B) with 95% confidence circles.

Field 18-5: the soil from this field had very good microbial activity and soil health index (48 and 47, considered as good to high). Soils from site A and B were very similar. However, soil from site A had slightly higher nitrogen levels, % saturation of phosphorus, potassium, magnesium, GFI and soil health index than the soil from site B. The productivity of this field is less than its potential due to the low pH levels (5.8 – 5.9). Considering the balanced fertility and soil health of this field, bringing up the pH to 6.2 - 6.5 should increase yields.

Microbial communities

No differences were found in the microbial communities of roots from site A and B (Figure 2). Our previous results have shown that when the fertility of soils is very similar, independently of fertility level, no differences in the microbiology of plants growing in those soils can be identified using TRFLP analysis

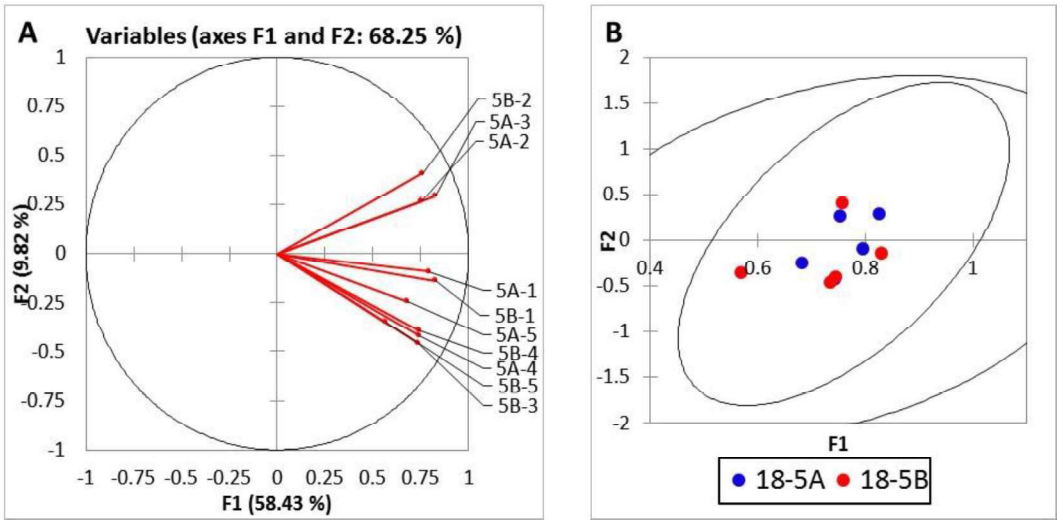

Figure 2. Statistical analysis of TRFLP results for the bacterial communities in corn roots of 18-5A and 18-5B. Bacterial communities are represented as vectors (A) and as points(B) with 95% confidence circles.

Field 18-6: soil from the B site of this field had an overall higher microbial activity and soil health. On average, B soil had a GFI of 60, considered medium, while A soil had a GFI of 52, considered low. Site B had a higher % saturation of potassium, magnesium, and phosphorus than site A, and had a soil health index of 40, considered medium to good, while site A had a soil health index of 31 considered low to medium. The pH on both sets of soil was low (pH 5.1), reducing the yield potential of this field.

Microbial communities

As shown on Figure 3, the microbial communities from roots from site A and B were somehow different. The vectors that represent the microbial communities of site A clustered all together on the top right quadrant of the graph, while the majority of the vectors representing site B clustered on the bottom right quadrant. The exception were samples 6B-1 and 6B-4 (Figure 3A, highlighted in yellow). The microbial populations of those plants shared similarities with the plants from both sites.

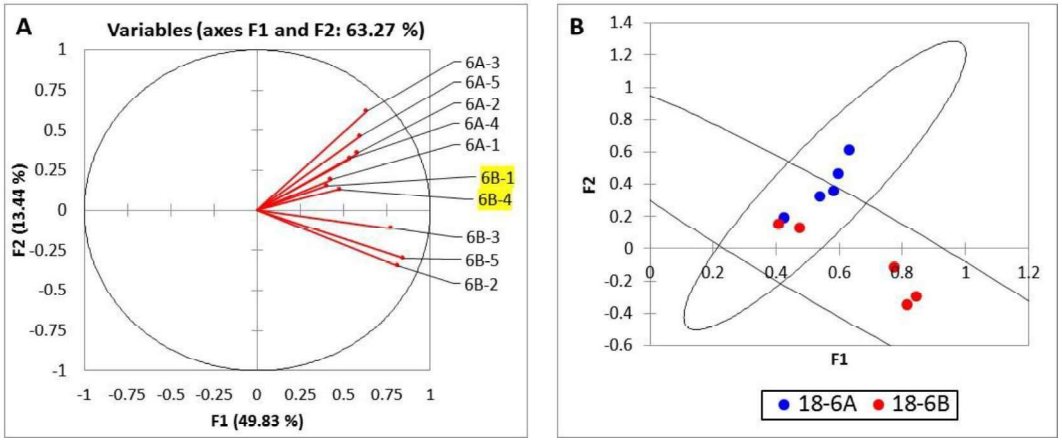

Figure 3. Statistical analysis of TRFLP results for the bacterial communities in corn roots of 18-6A and 18-6B. Bacterial communities are represented as vectors (A) and as points(B) with 95% confidence circles.

Conclusions

The soil health test gives a complete overview of the chemical and microbial status of a soil and allows us to identify the differences that exist in areas with different productivity levels. Only on those fields with different fertility level we found differences in the microbiome of plants growing on those fields.