Back to the future: building and maintaining soil health will require new ways to do agriculture

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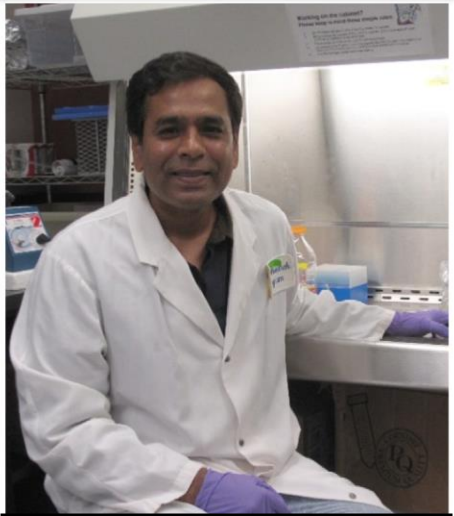
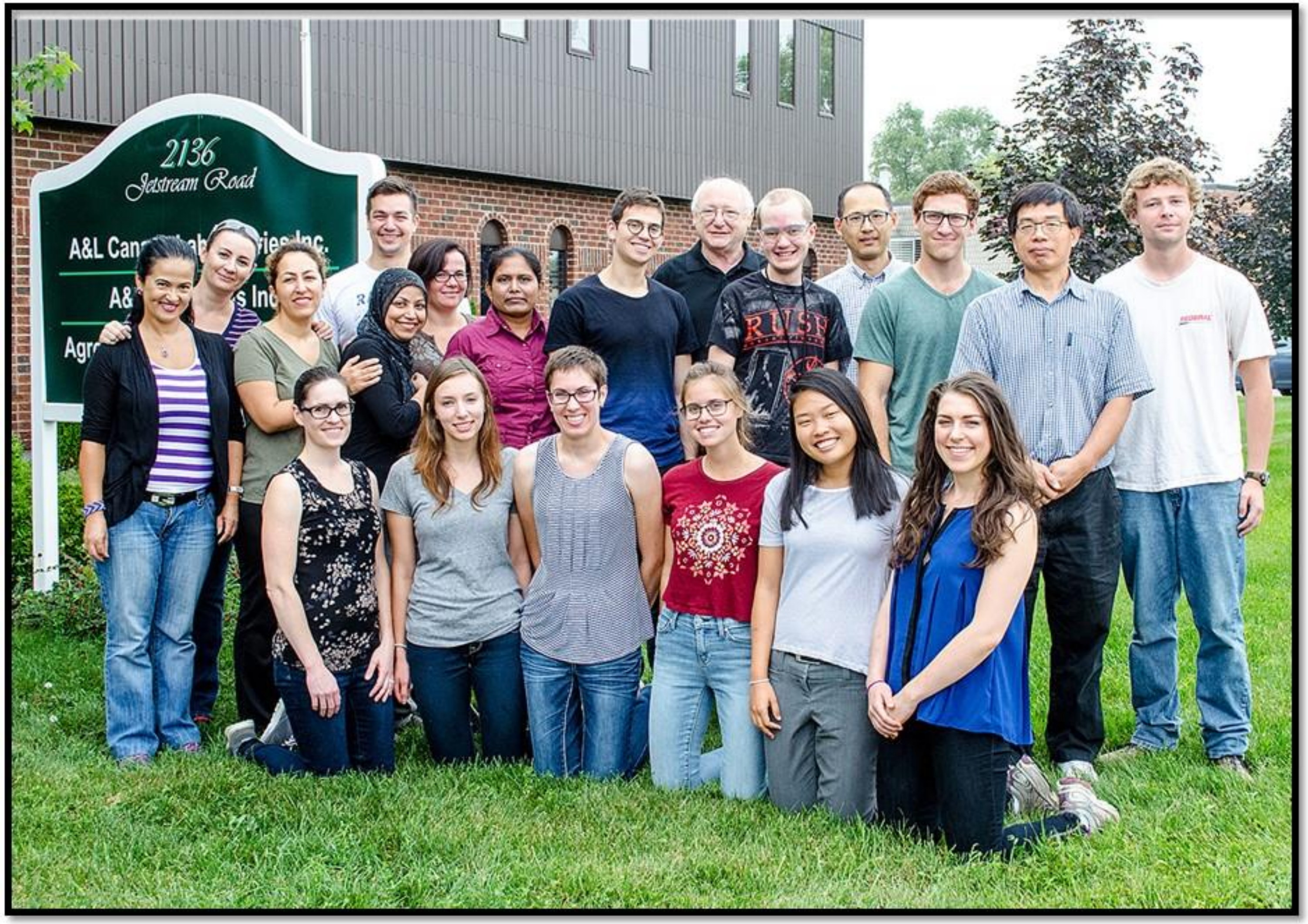


Dr Rafiq Islam
2012-2015



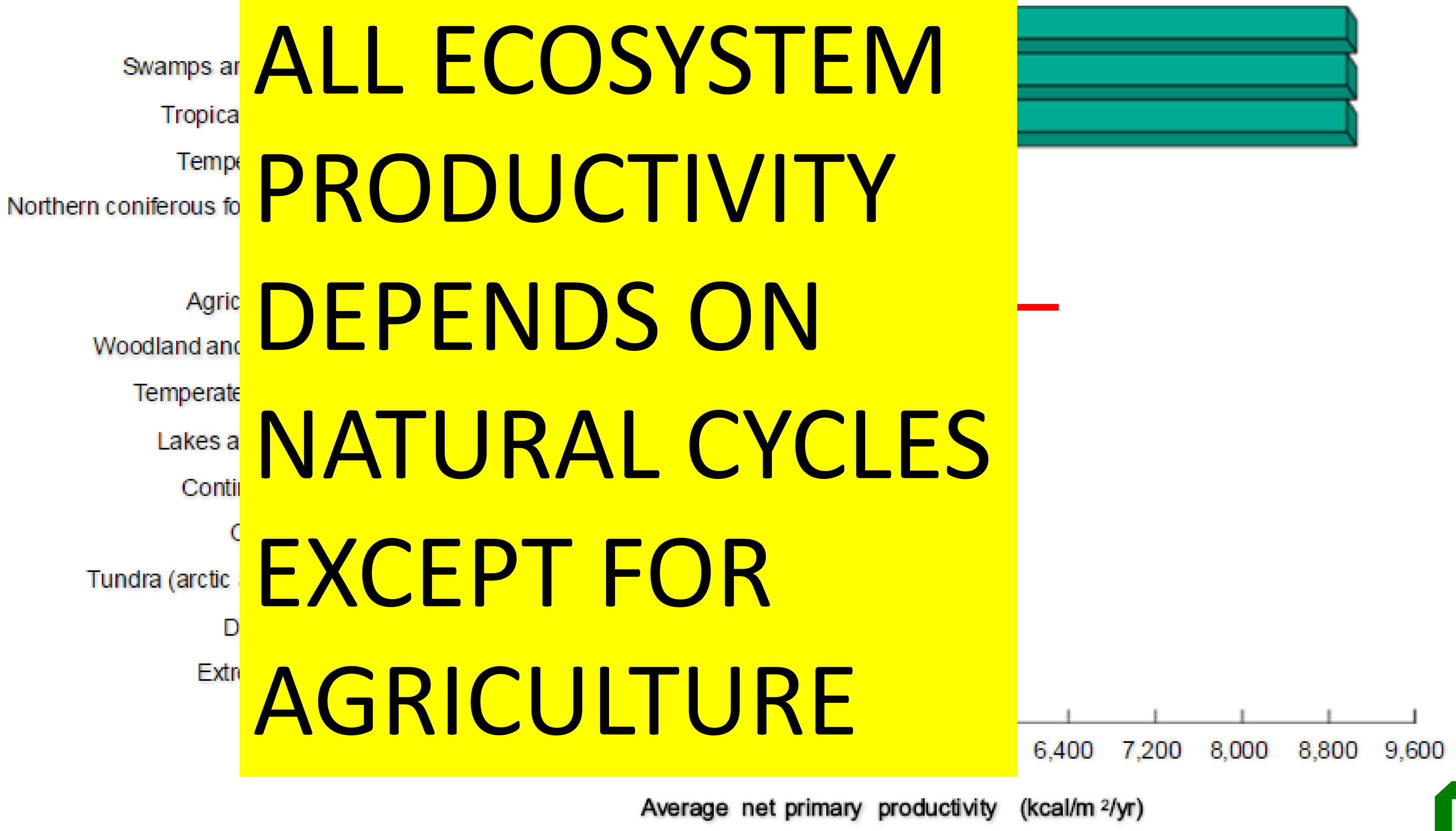
Doran et al. defined soil health as “the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health.” :

Doran, J.W., Liebig, M.A., Santana, D.P., 1998. Soil health and global sustainability. I Proceedings of the 16th World Congress of Soil Science. Montepellier, France, 20–26 August 1998.

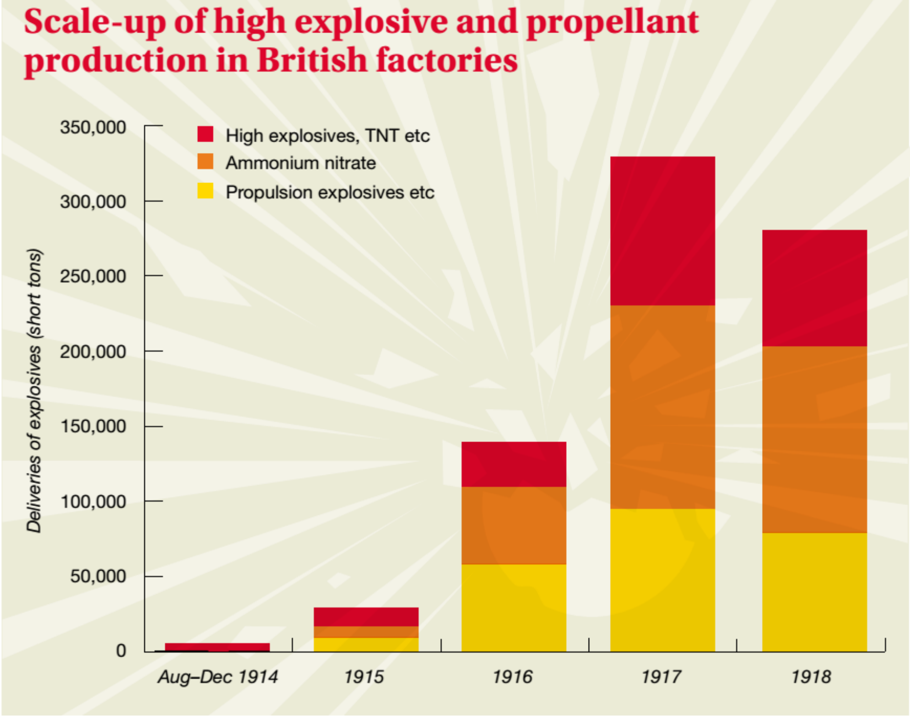
+ 1000 years =

ORGANIC MATTER ACCUMULATES BECAUSE SOILS ARE NITROGEN DEFFICIENT

ALL ECOSYSTEM PRODUCTIVITY DEPENDS ON NATURAL CYCLES EXCEPT FOR AGRICULTURE



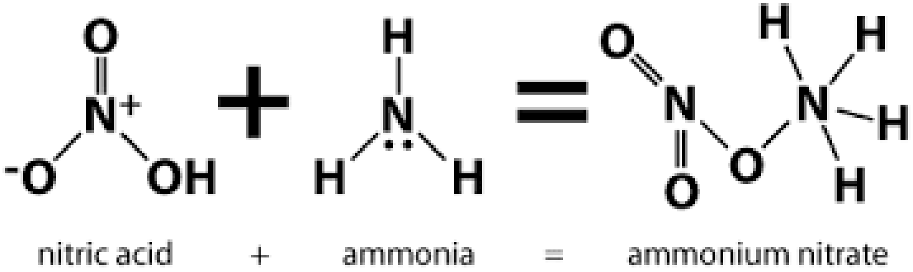
•Nobel Peace Prize (1970)



The Second Green Revolution

Greatly based on the Haber–Bosch nitrogen patents

Production of Ammonium Nitrate Fertilizer



Norman Borlaugh
Nobel Peace Prize
(1970)

Negro farmer hauling bags of dry fertilizer onto his truck, San Augustine, Texas, 1939. FSA.




We have destroyed a third of Earth's farmland in 40 years

- Soil is being destroyed 100 X faster than it can form
- to avert disaster, farmers must adopt sustainable agricultural practices based on ecological principles.

http://news.sciencemag.org/sifter
USDA NRCS SOUTH DAKOTA/FLICKR (CC BY-SA 2.0)

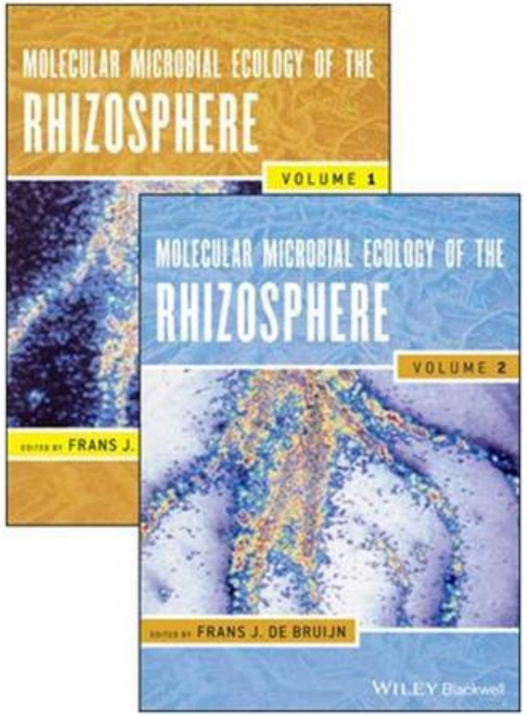
HOME SEARCH The New York Times

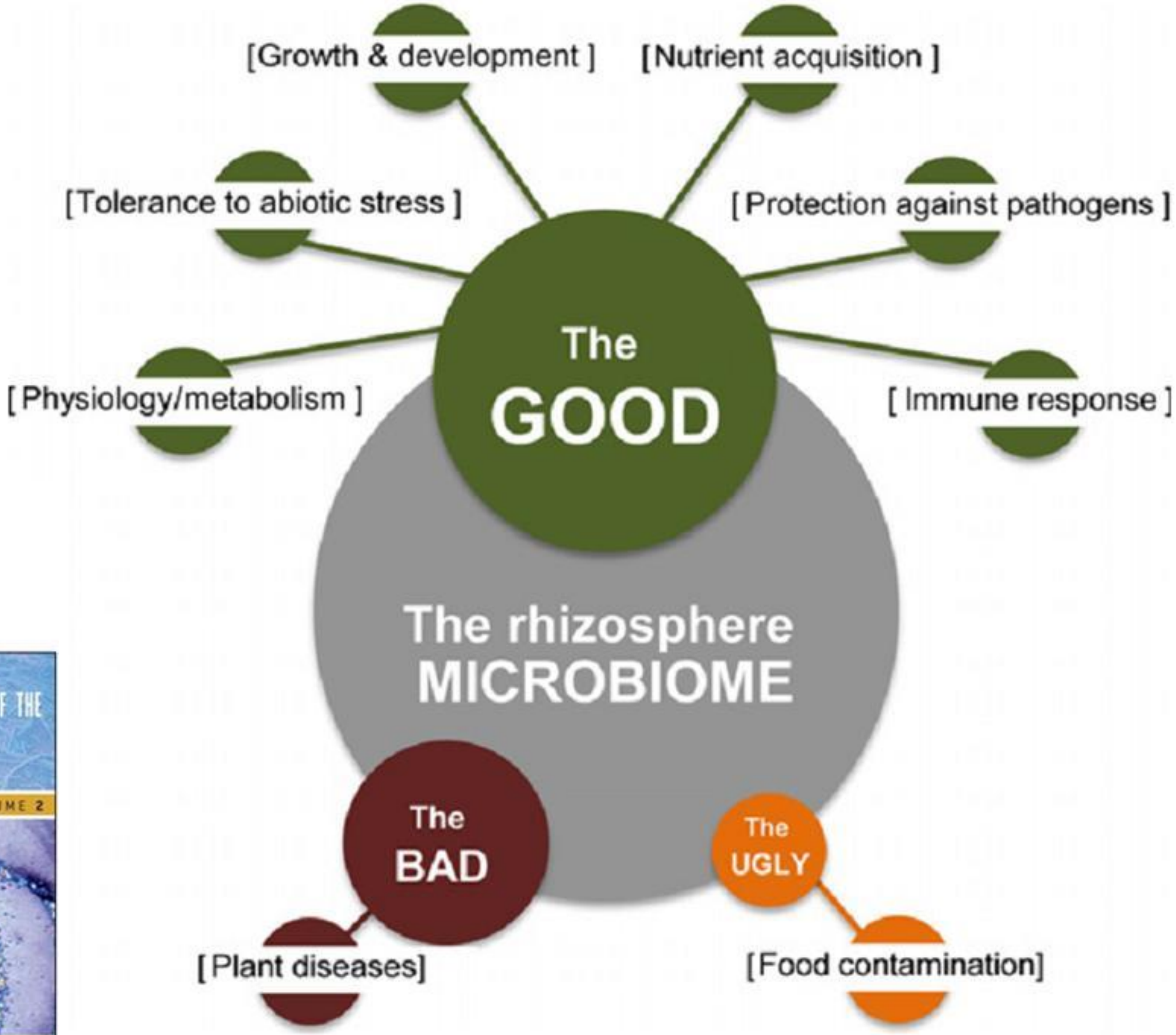
The Opinion Pages | OP-ED CONTRIBUTORS

We Need a New Green Revolution

JANUARY 4, 2016

By PHILLIP A. SHARP and ALAN LESHNER JAN. 4, 2016





FEMS Microbiol Rev37(2013) 634–663

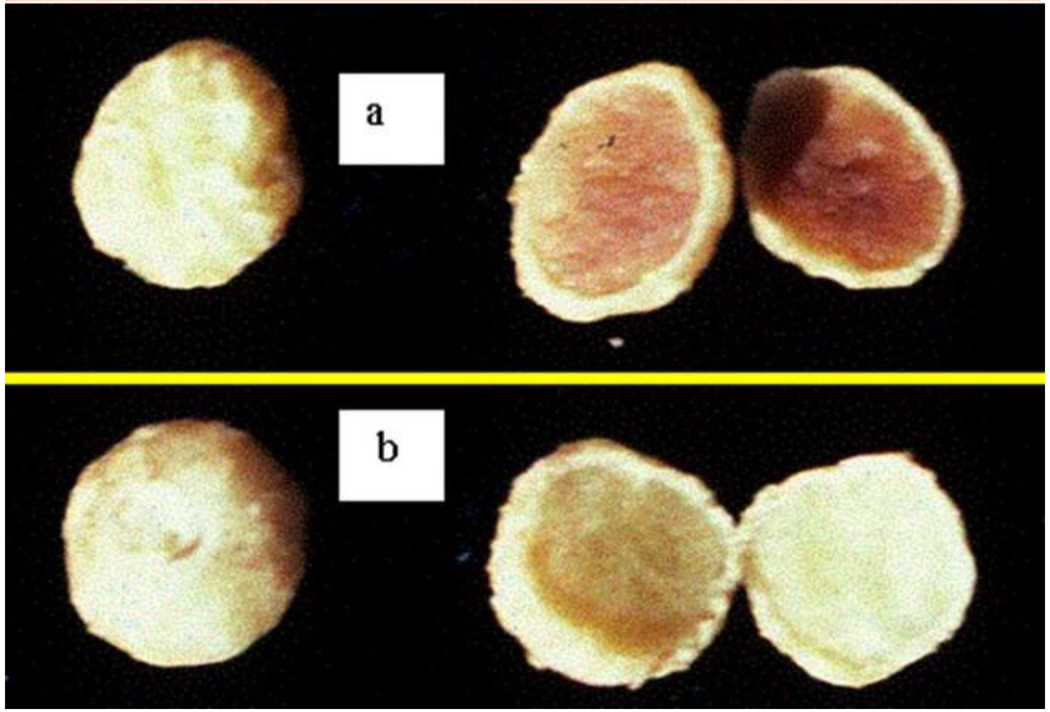
Estimated Net Productivity of Certain Ecosystems
kilocalories/m^2/year

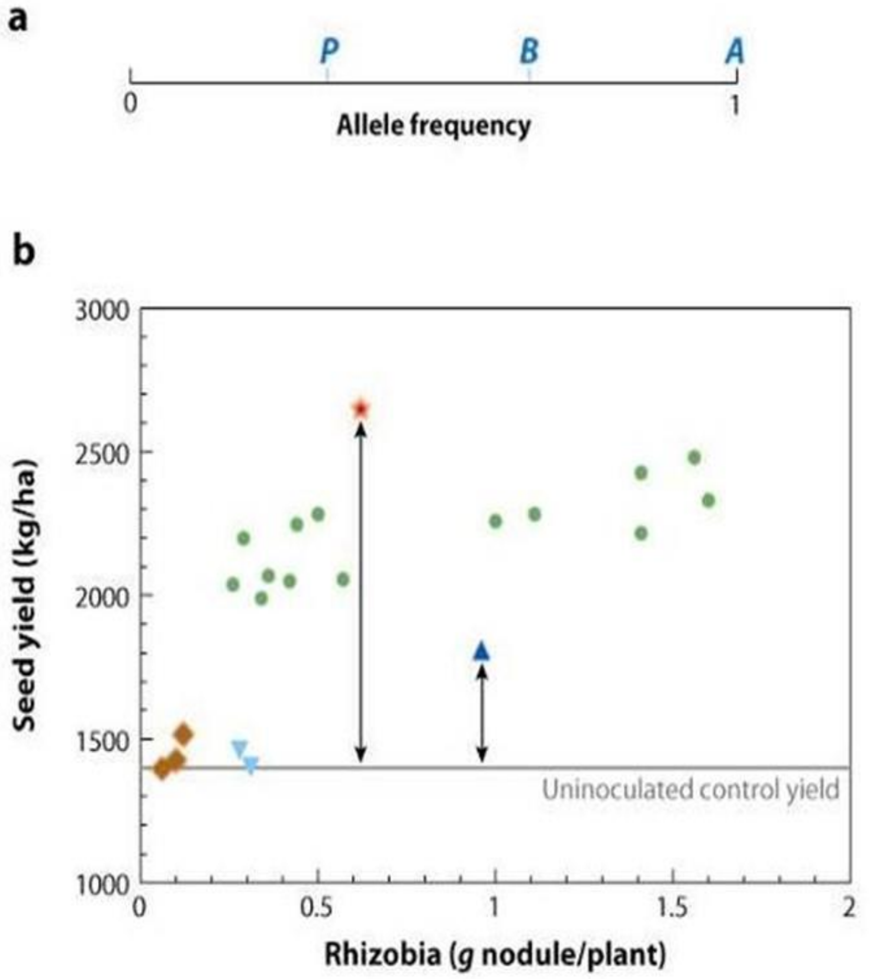
Temperate deciduous forest	5,000	
Corn (maize) field, U.S.	4,500	3)
Rice paddies, Japan	5,500	
Lawn, Washington, D.C.	6,800	
Tropical rain forest	15,000	
Coastal marsh	12,000	
Field of alfalfa (lucerne)	15,000	1)
Sugar cane, Hawaii	25,000	2)

- Legume crops and pasture species fix as much as 200 to 300 kg nitrogen per hectare (Peoples et al., 1995).
- Globally, symbiotic nitrogen fixation has been estimated to amount to at least 70 million metric tons of nitrogen per year (Brockwell et al., 1995).
- By 2018 global N usage is expected to surpass 200 million tonnes http://www.fao.org/news/story/en/item/277488/icode/

Peoples et al. 1995. Plant Soil 174:3–28,
Brockwell et al. 1995. Plant Soil 174:143–180

ARE ALL RHIZOBIUM INTERACTIONS BENEFICIAL?





Kiers ET, Denison RF. 2008.
Annu. Rev. Ecol. Evol. Syst. 39:215–36

Plant Soil (2010) 336:129–142
DOI 10.1007/s11104-010-0454-7

REGULAR ARTICLE

Enhancement of rice production using endophytic strains of *Rhizobium leguminosarum* bv. trifolii in extensive field inoculation trials within the Egypt Nile delta

Youssef G. Yanni · Frank B. Dazzo

- Large-scale field experiments evaluated 5 rice varieties X 7 endophytic Rhizobia strains over 5 seasons, including **sites ranked as the world's highest in rice production**.
- Inoculation increased yield in 19 of the 24 trials.
- Increased yields were up to 47% in farmers' fields; average 19.5%.
- Potential billions in increased rice yields at reduced cos
environmental impacts

A brief story of nitrogen fixation in sugarcane — reasons for success in Brazil

José I. Baldani[AB], *Veronica M. Reis*[A], *Vera L. D. Baldani*[A] *and Johanna Döbereiner*[†]

[A]Embrapa Agrobiologia – C.P. 74.505, CEP 23851–970 Seropédica, Rio de Janeiro, Brazil.
[B]Corresponding author; email: ibaldani@cnpab.embrapa.br
[†]In memoriam

1. **Introduced into Brazil in 1532, grown for 400 years without any fertilizer; now 40 million Ha grown**
2. **In plant breeding selection of cultivars was based on minimal reliance on nitrogen**
3. **Early research identified the need to use microbes that supported plant growth and productivity**

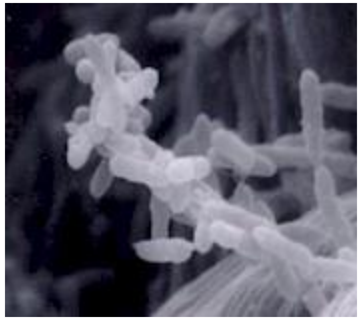
Table 3. Nitrogen fertilizer levels applied to sugarcane plants grown in different countries

Source: IFA (1999)

Country	Nitrogen fertilizer (kg ha^{-1})
Argentina	100
Australia	150–250
Brazil	50
India	100–300
Mexico	120–200
Philippines	120–200
South Africa	80–120
USA — Hawaii	300–400

Sugar cane endophytes are integral components of production

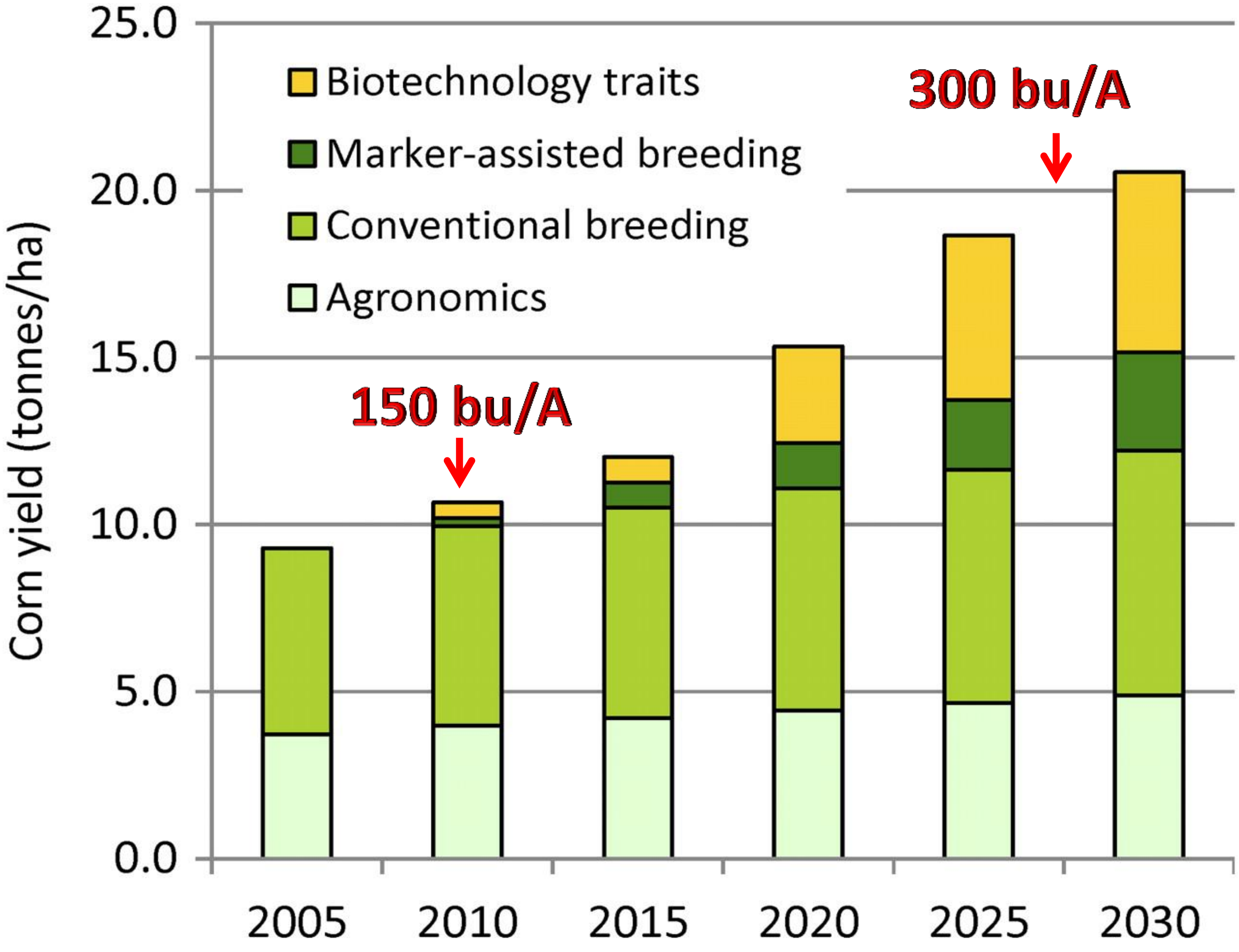
- **bacterial edophytes provided the crop its nitrogen**
- **Endophytes include: *Gluconacetobacter diazotrophicus*, *Herbaspirillum spp.*, *Azospirillum* spp. and *Burkholderia* spp.**
- ***G. d.* has been isolated from coffee, pineapple, sweet potato, etc.; can solubilize zinc and phosphate, produces auxins, antagonizes pathogens**



Gluconacetobacter diazotrophicus

azotic TECHNOLOGIES

Anticipated impact of improvements in agronomics, breeding, and biotechnology on average corn yields in the United States.



Edgerton M D Plant Physiol. 2009;149:7-13

Fence Row Farming – Improving Soil Processes

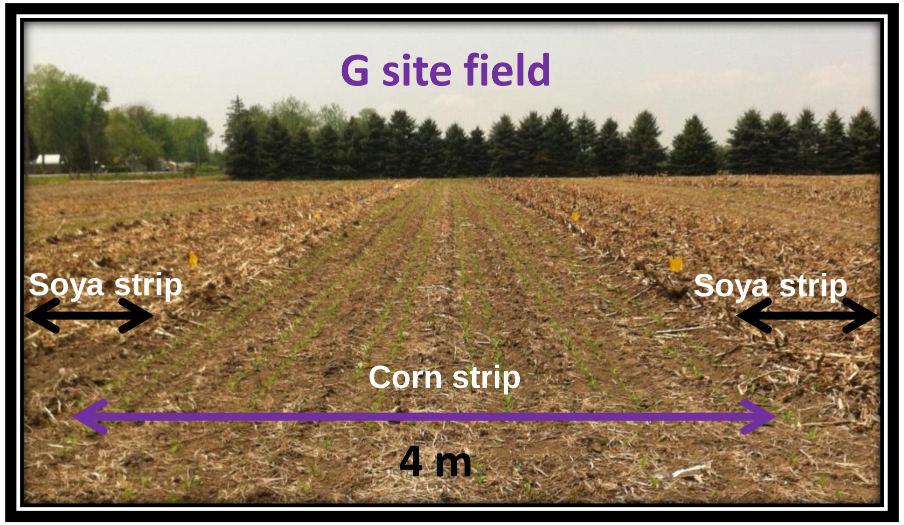
Mr. and Mrs. Dean Glenney, Dunnville, Ontario

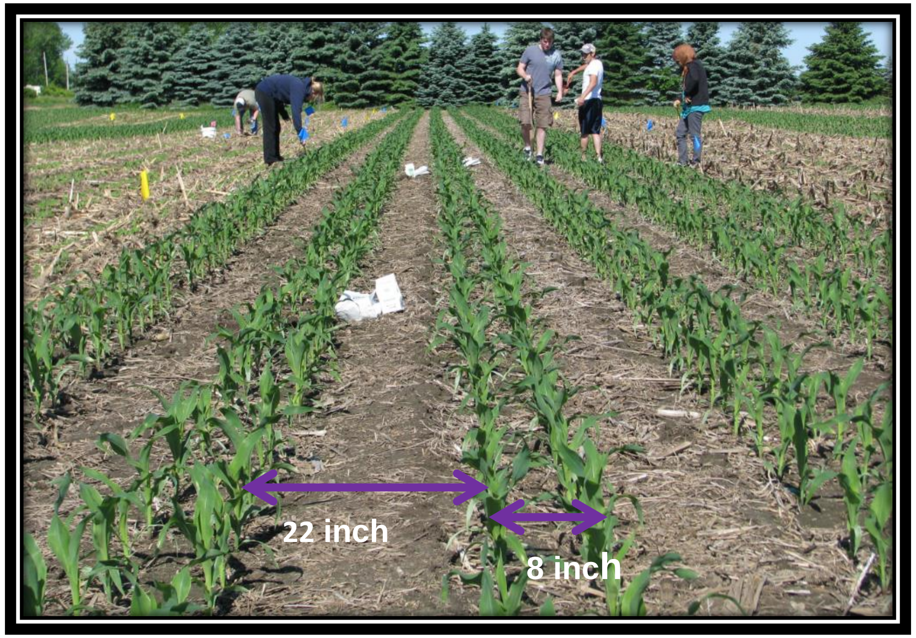
Average Corn Yield at 301 bu/acre for corn and 62 bu/acre soybeans; yields 2X times that of the county average

Identification of physical, chemical and biological factors involved in corn productivity

High yielding G site corn production field

No-till strip row farming practice



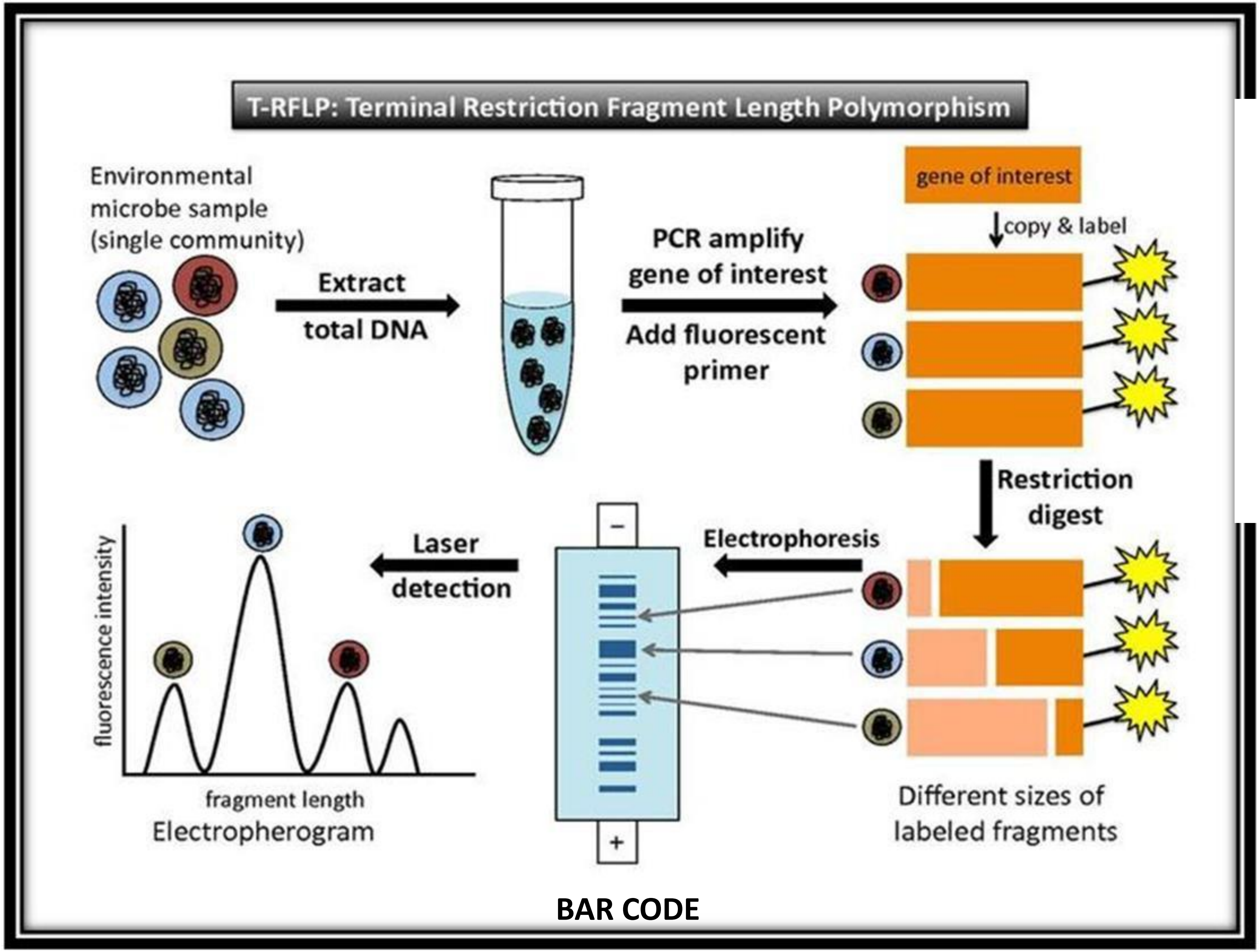


Conventional field (H site)

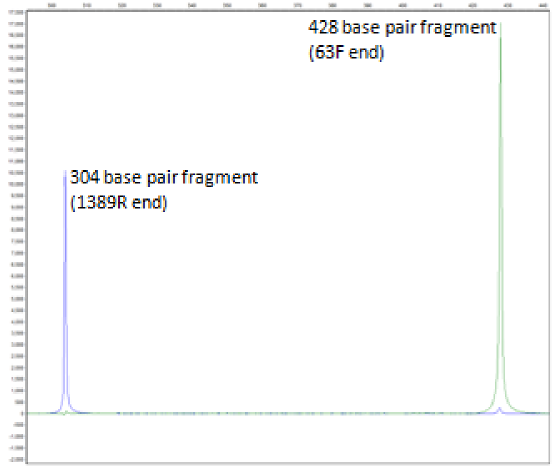
Harvested corn ears from G and H sites

G site ear

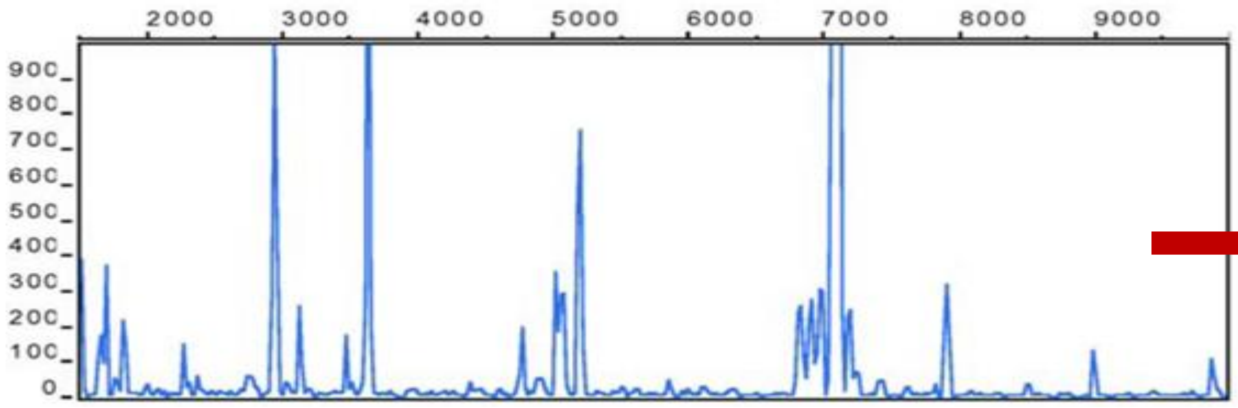
H site ear



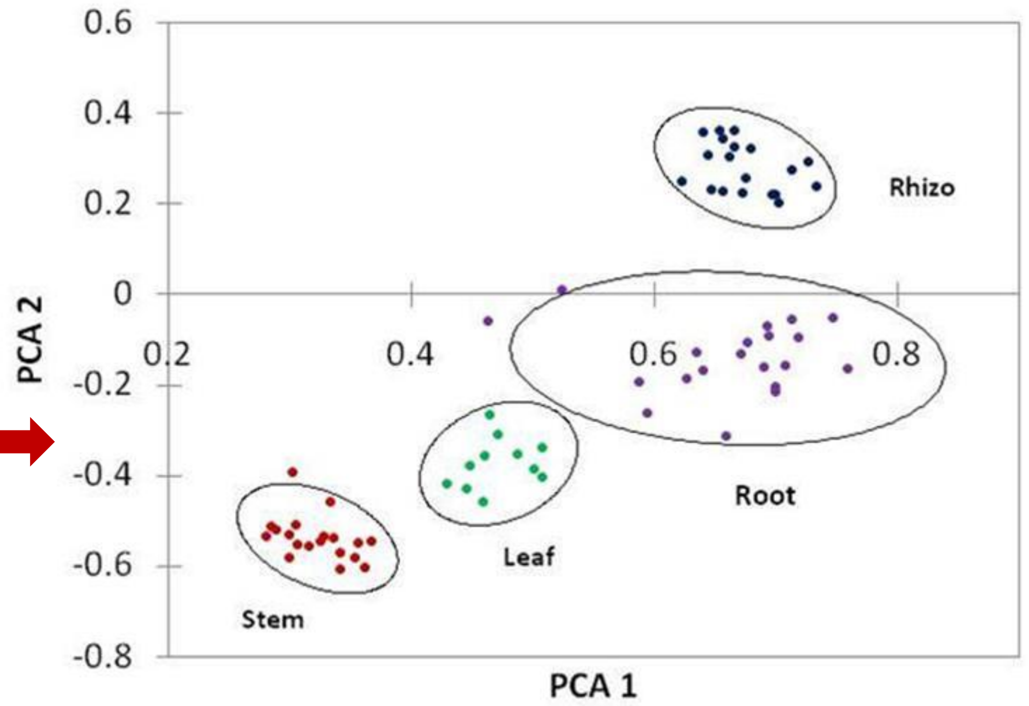
TRFLP Chromatogram of *Streptomyces scabies* amplified with 63F and 1389R then cut with HhaI



Bacterial diversity analysis using TRFLP technique

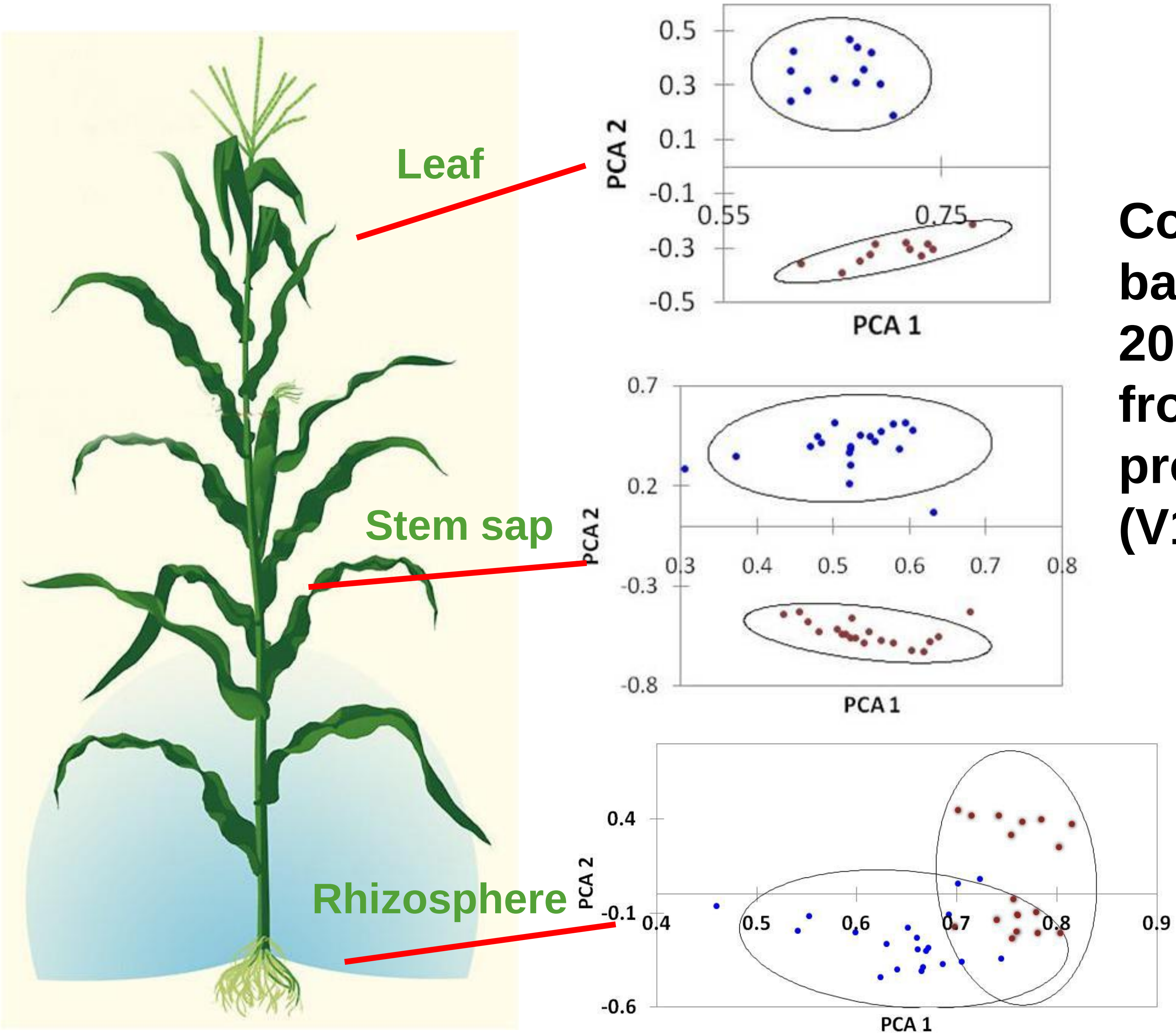


Chromatogram of TRFLP data



Principal component analysis (PCI)

TRFLP of bacteria populations in various corn tissues of 20 plants sampled from a high yielding soil at 60 days (V10) after planting.

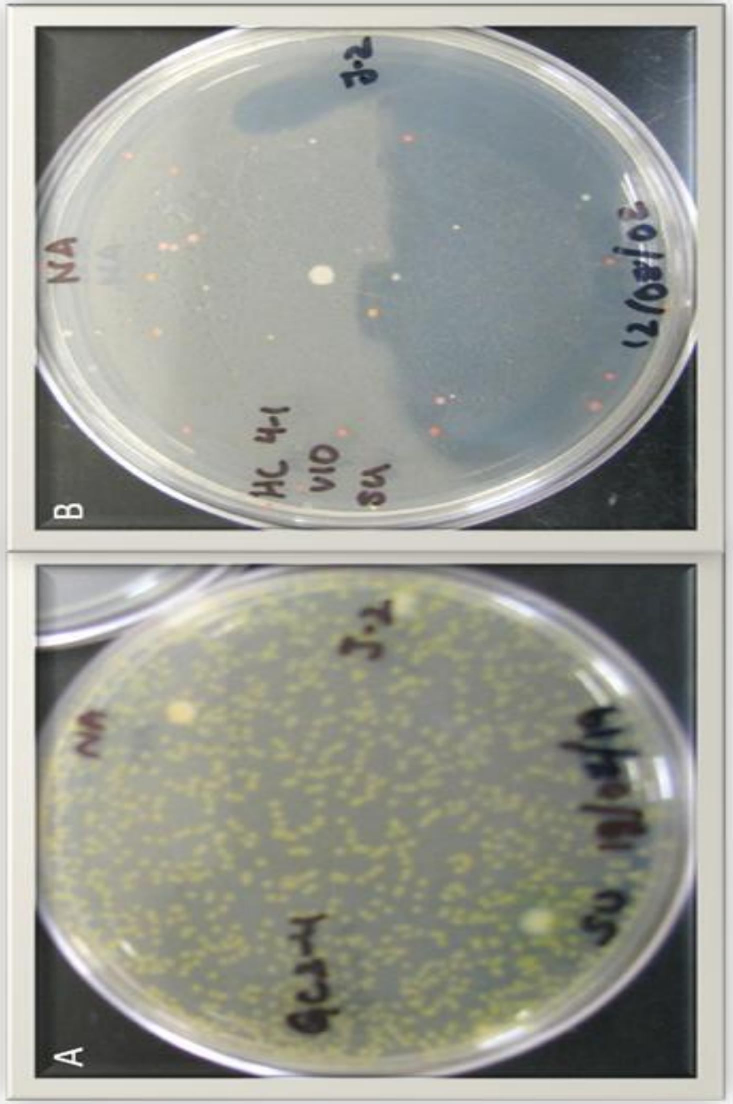


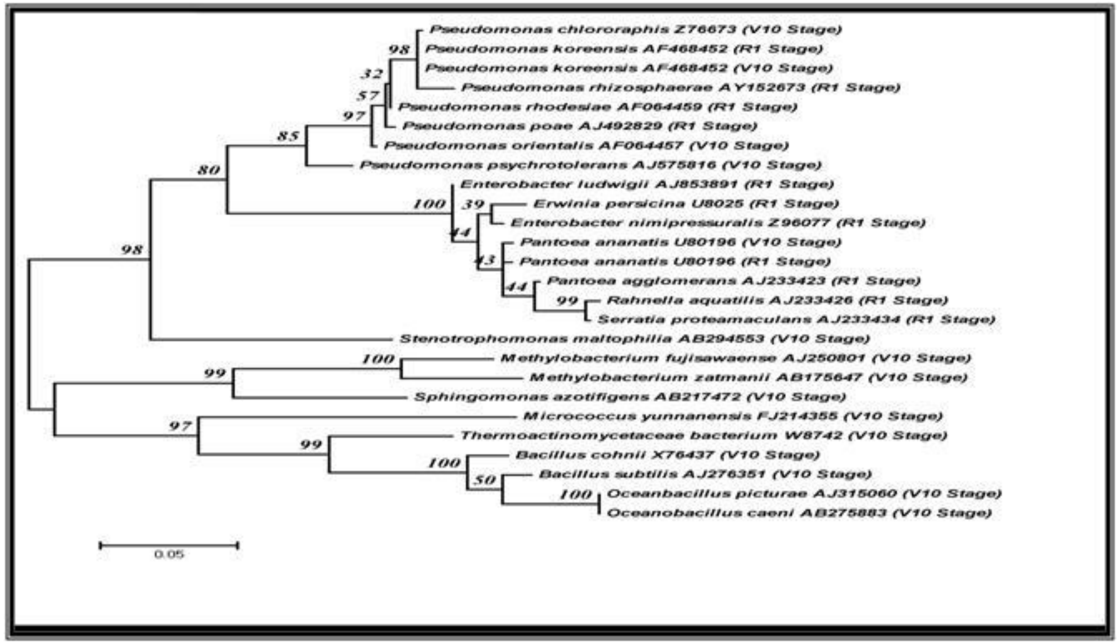
● = 150 Bu/A

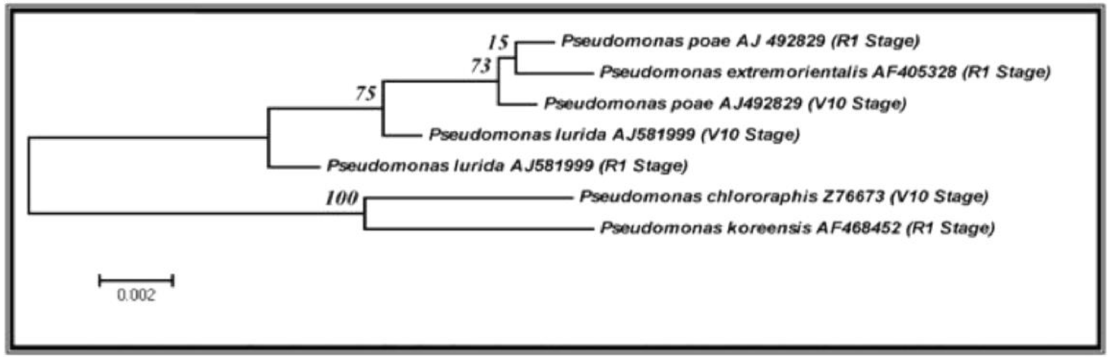
● = 300 Bu/A

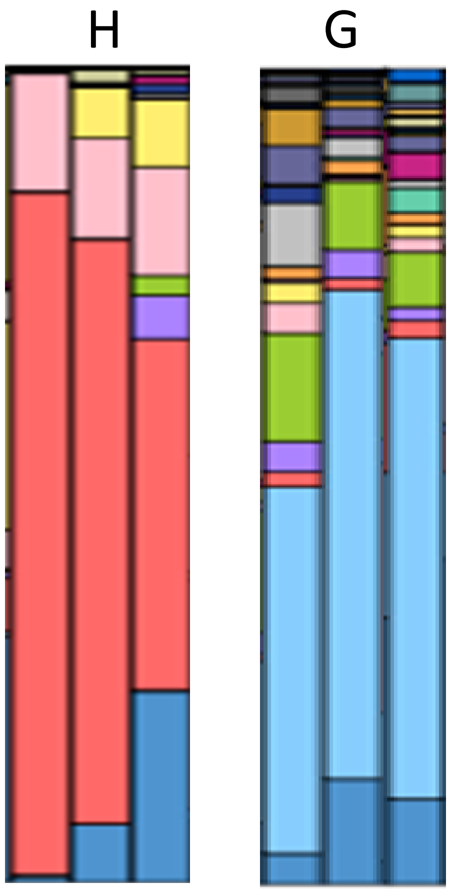
Comparison of bacterial TRFLP profiles of 20 corn plants harvested from a high and average production site at 60 days (V10) after planting

Bacteria isolated from stem sap of corn plants from G and H sites at V10 growth stage.





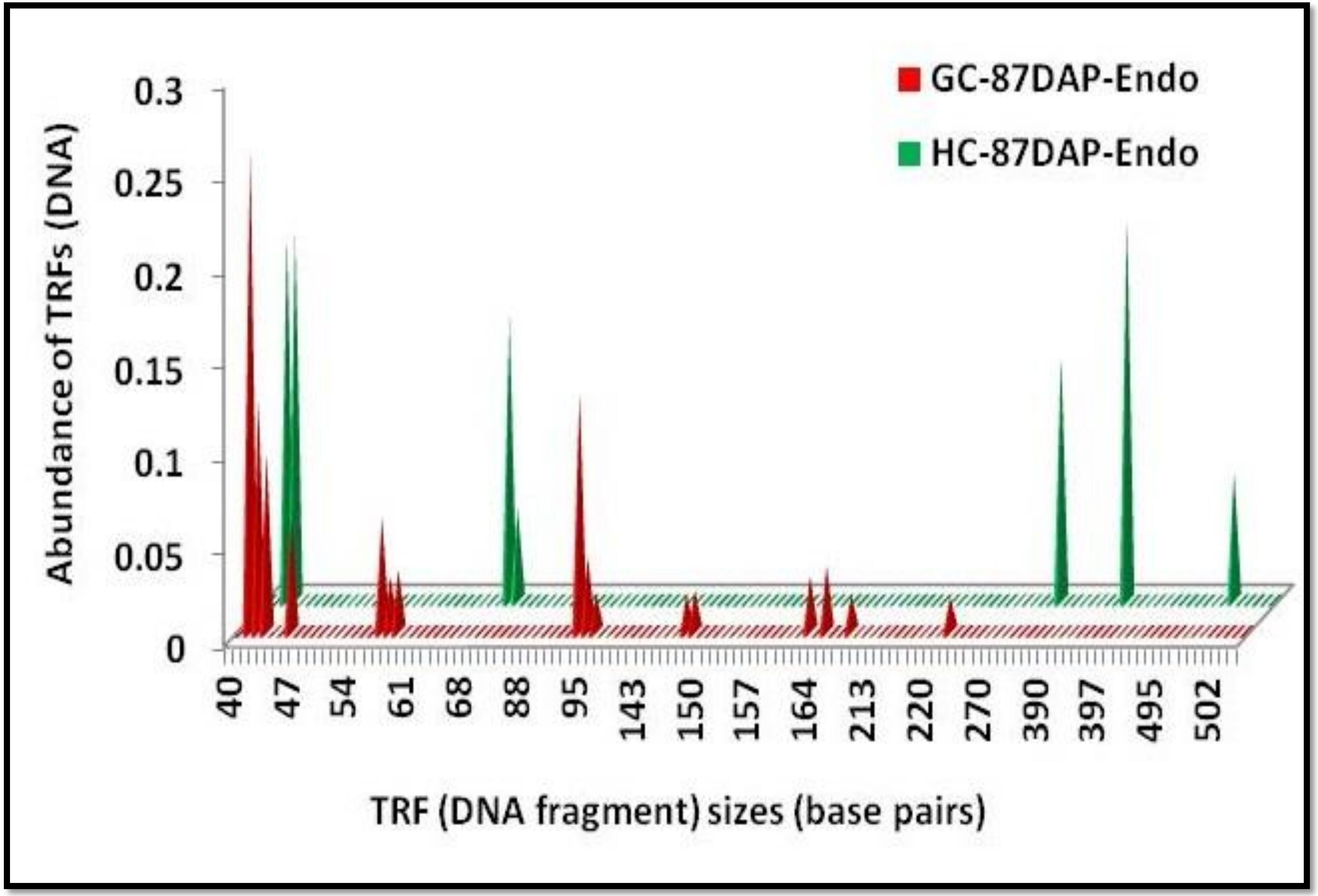




Farm Management Effects on Rhizosphere Colonization by Native Populations of 2,4-Diacetylphloroglucinol-Producing *Pseudomonas* spp. and Their Contributions to Crop Health

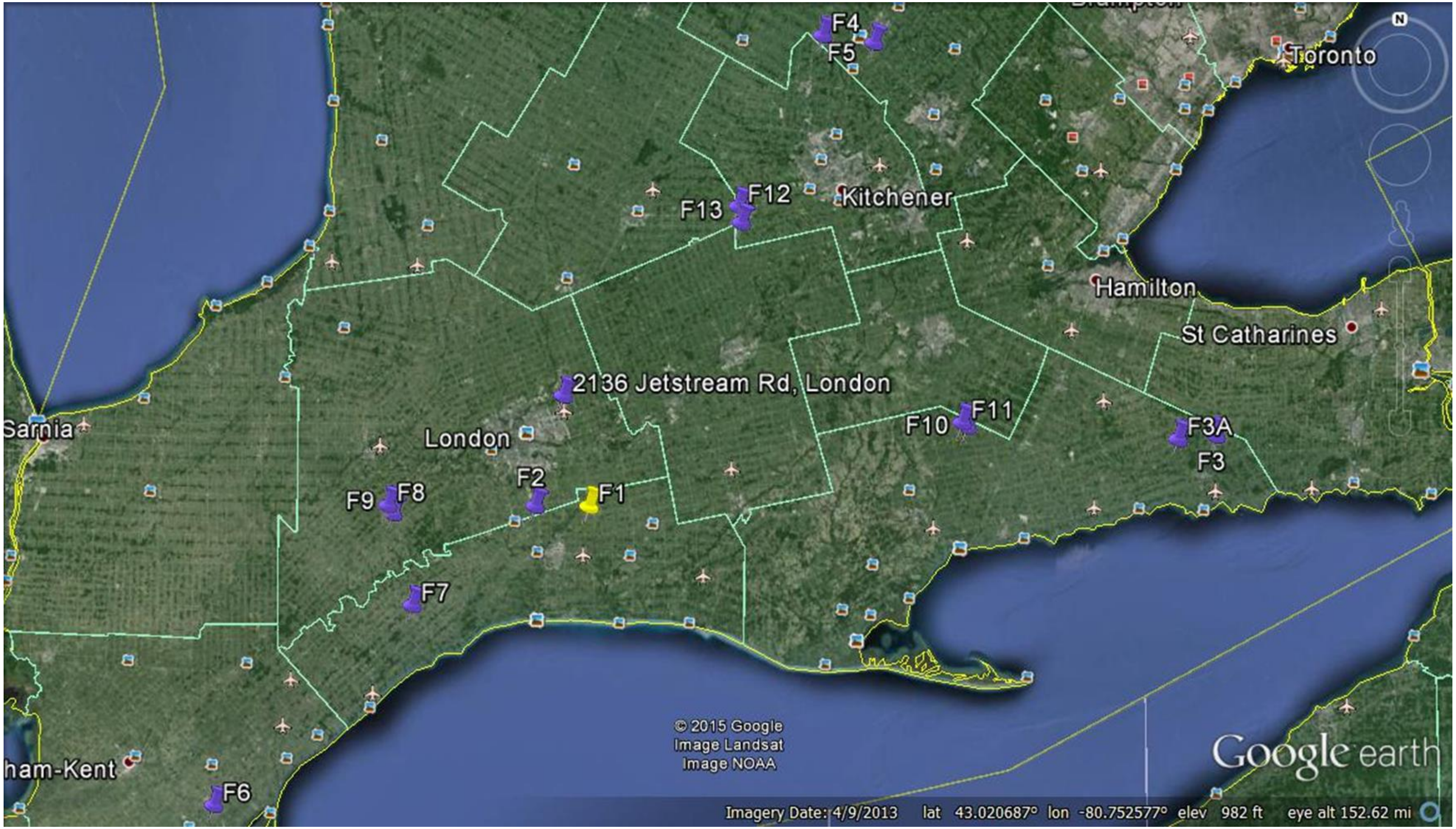
Dorith Rotenberg, Raghavendra Joshi, Maria-Soledad Benitez, Laura Gutierrez Chapin, Amara Camp, Clara Zumpetta, Adam Osborne, Warren A. Dick, and Brian B. McSpadden Gardener

Phytopathology
97:756-766



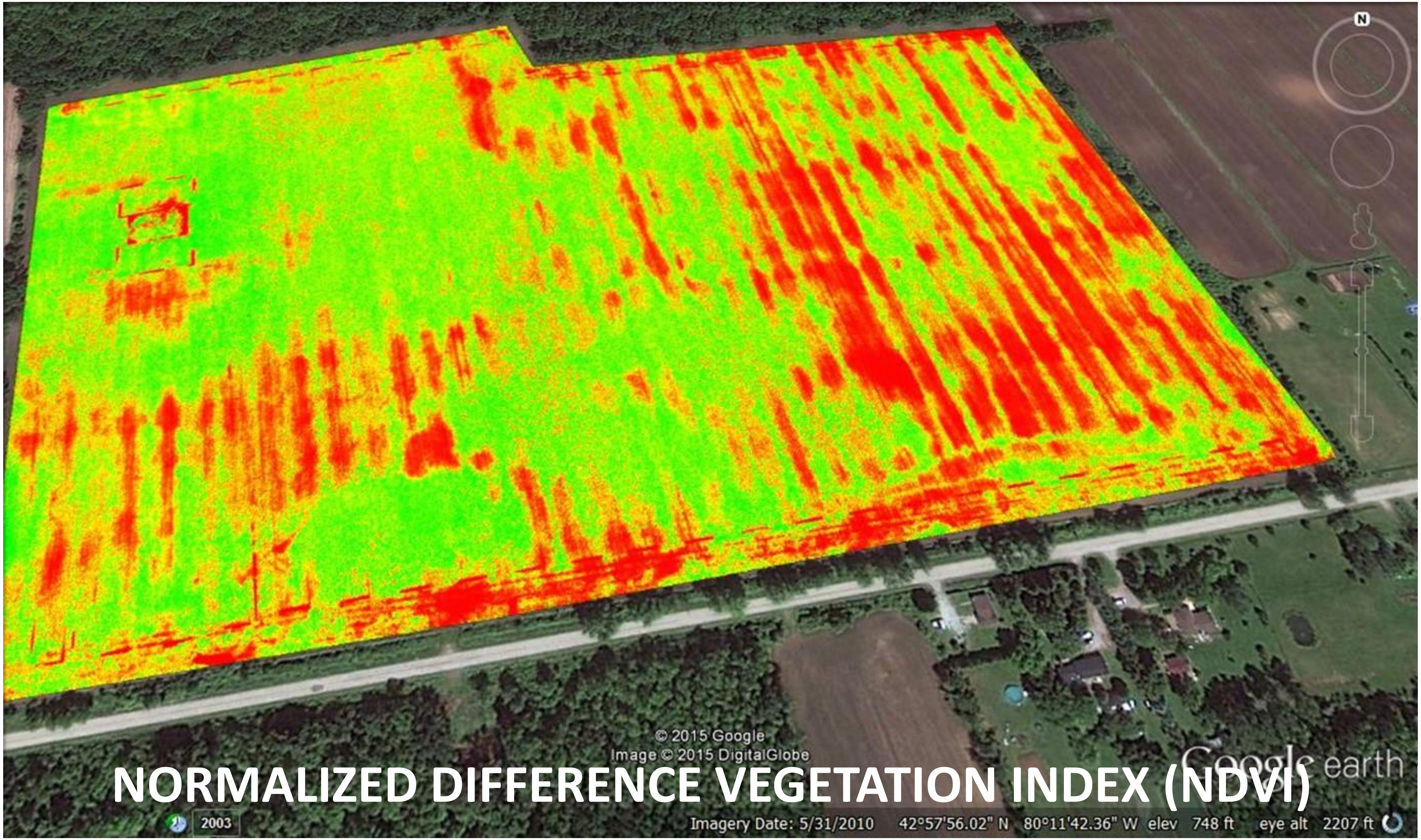
TRFLP of fungal populations inside corn stems harvested from a high and average production site at 60 days (V10) after planting

SAMPLING LOCATIONS IN ONTARIO

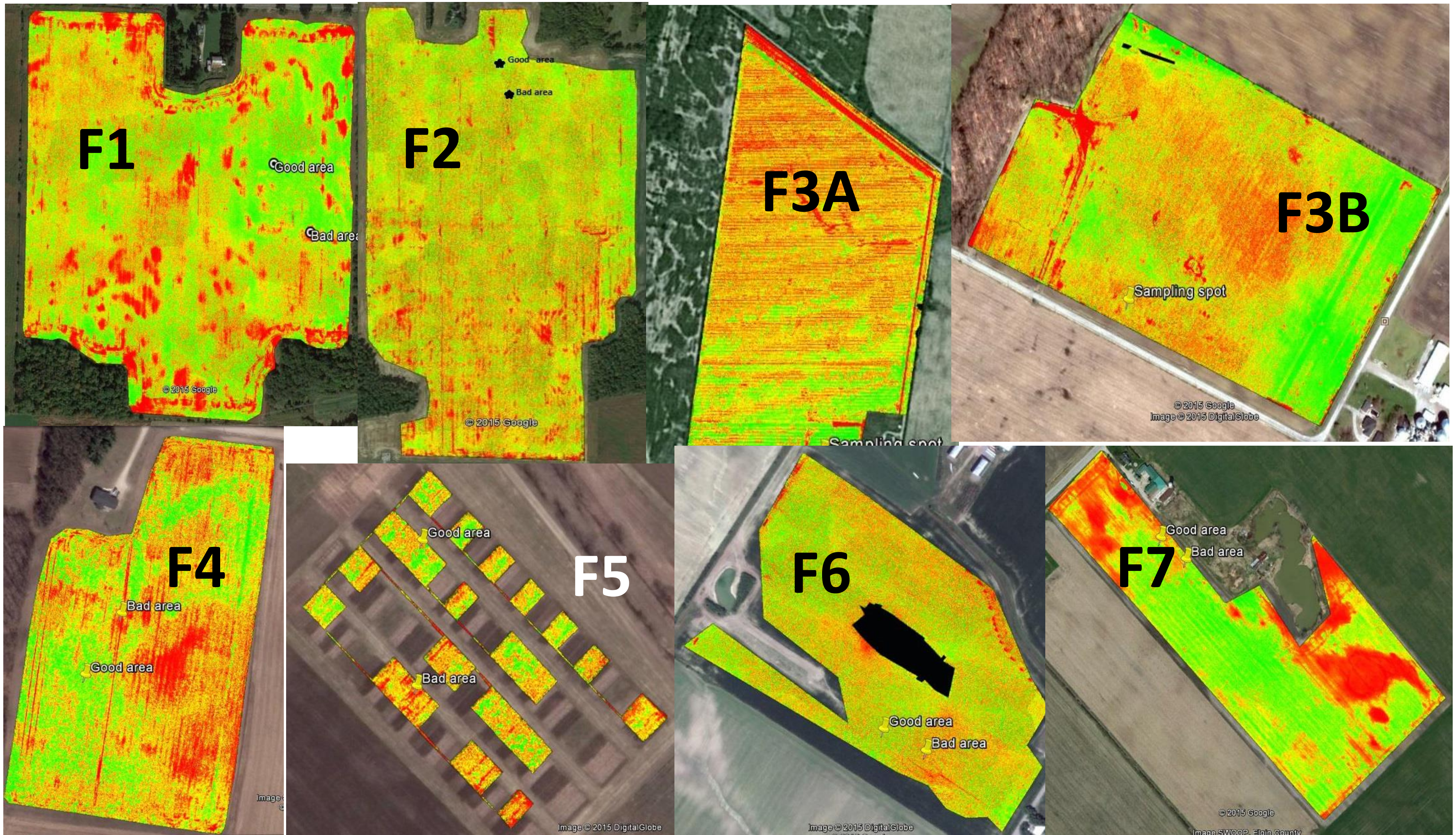


FIELD SAMPLING

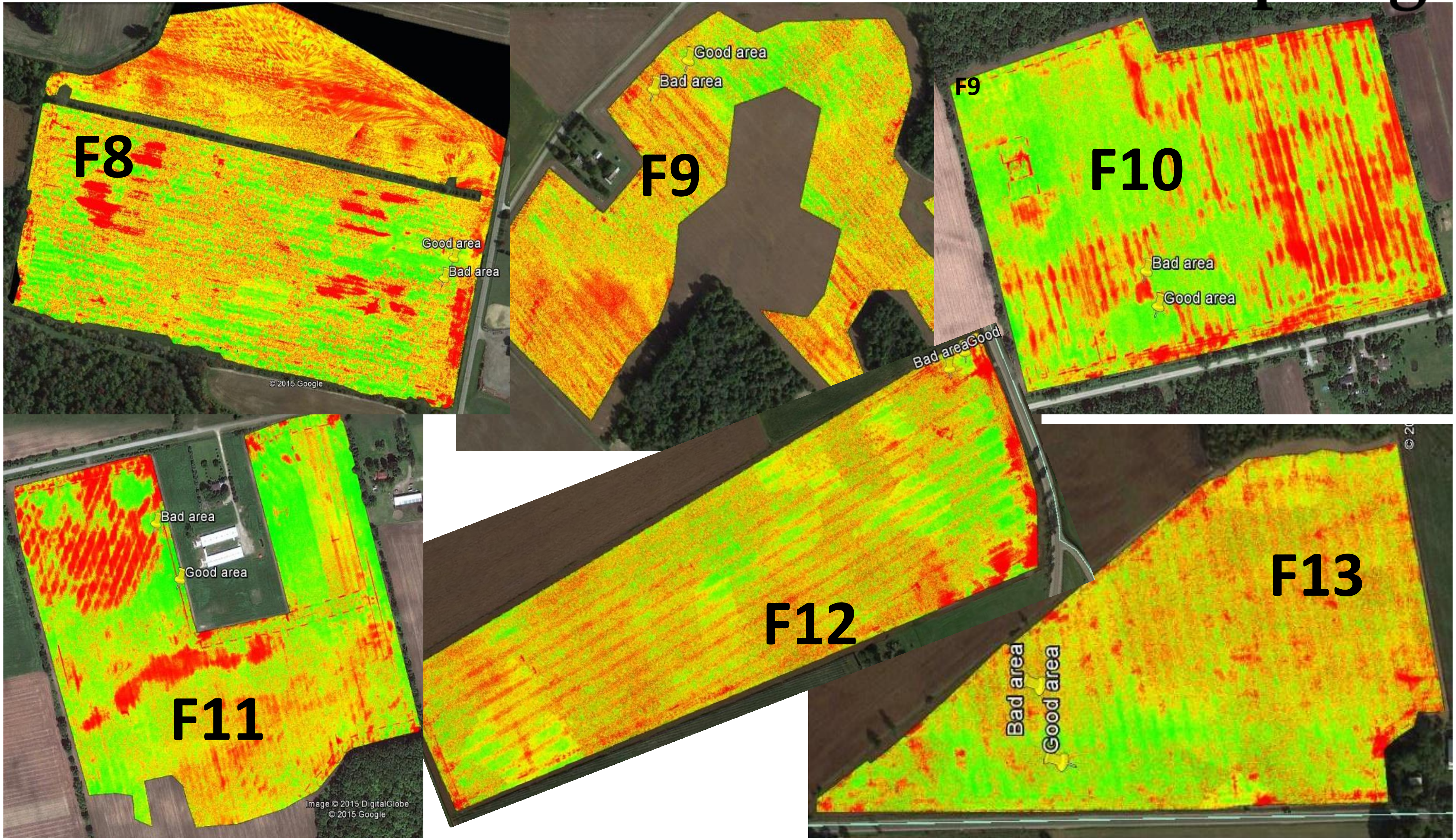
NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)



NDVI's of farms with marked sampling sites



NDVI's of farms with marked sampling sites



EVEN SMALL PLOTS HAVE ENORMOUS VARIABILITY AMONG THE PLANTS (UofG long term rotations)

Normalized difference vegetation index map (NDVI) and the combine yield harvested across the field

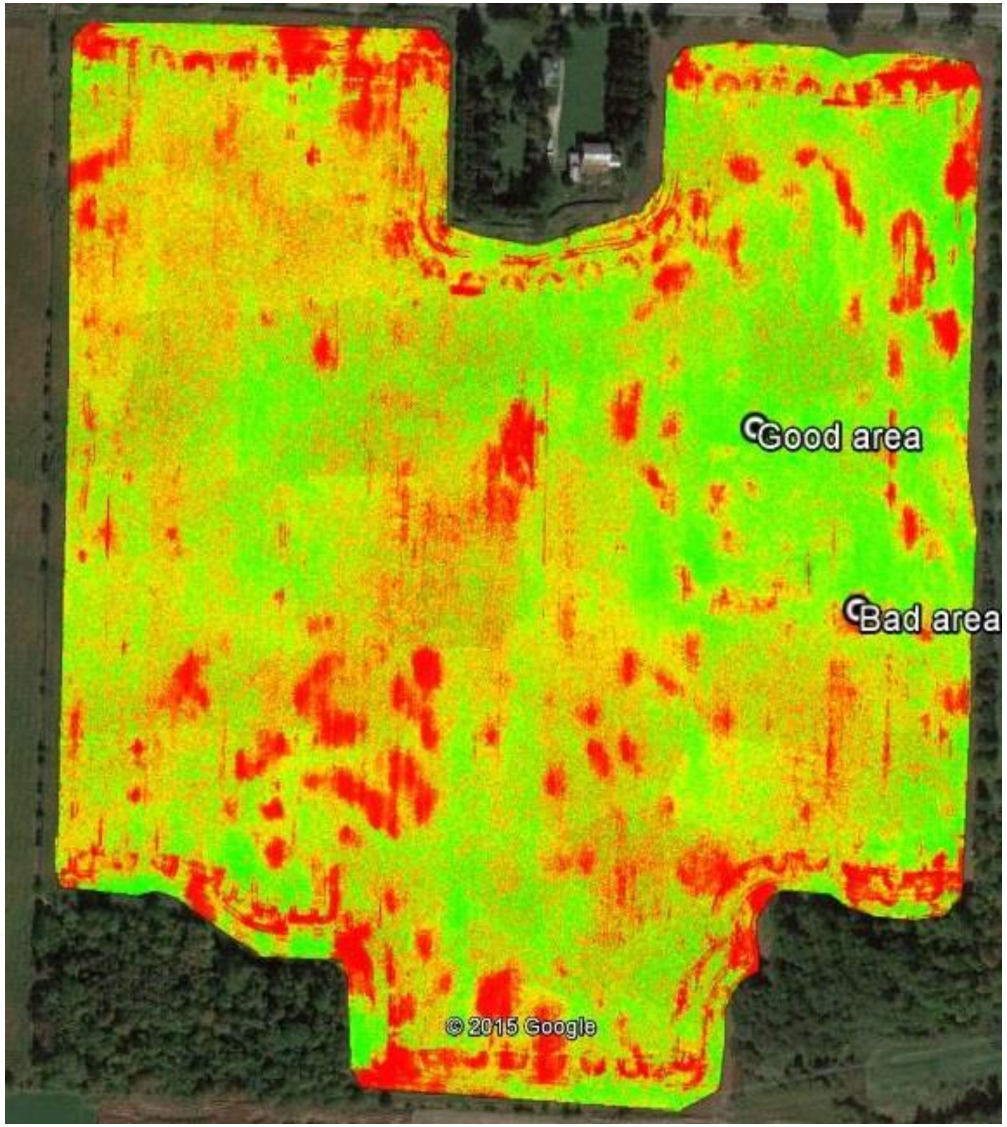
As-Applied Summary

4. Biologicals (Corn) | Fergusons | Home
2015 | Grain Harvest | CORN | Harvest - 1

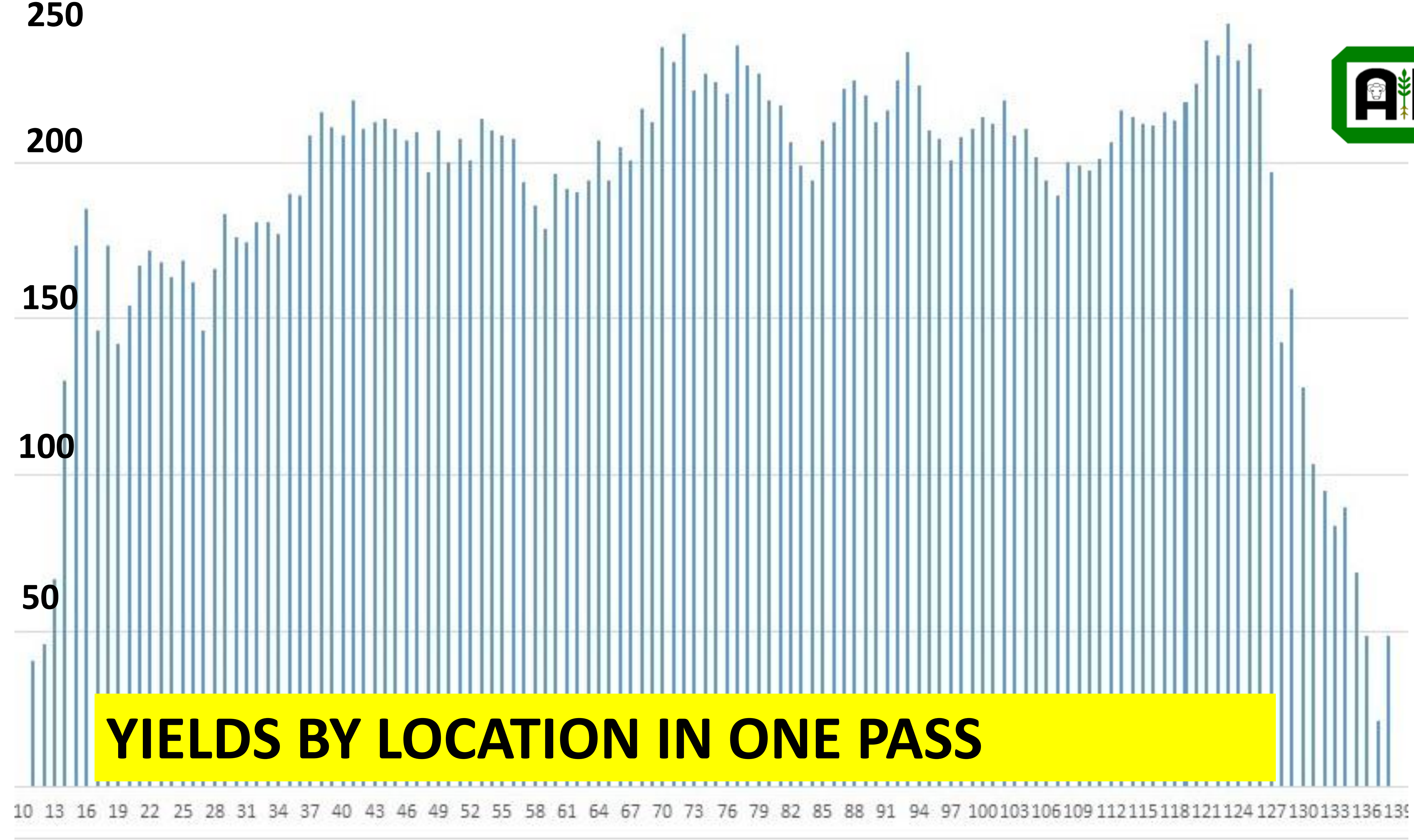
Dataset	Area ac	Est. Volume (Dry) bu	Avg. Yield (Dry) bu/ac	Date Logged
L0:Ferguson Bros.-(	0.00	0.00	184.15	1/18/2016

Estimated Volume (Dry)
(bu/ac)

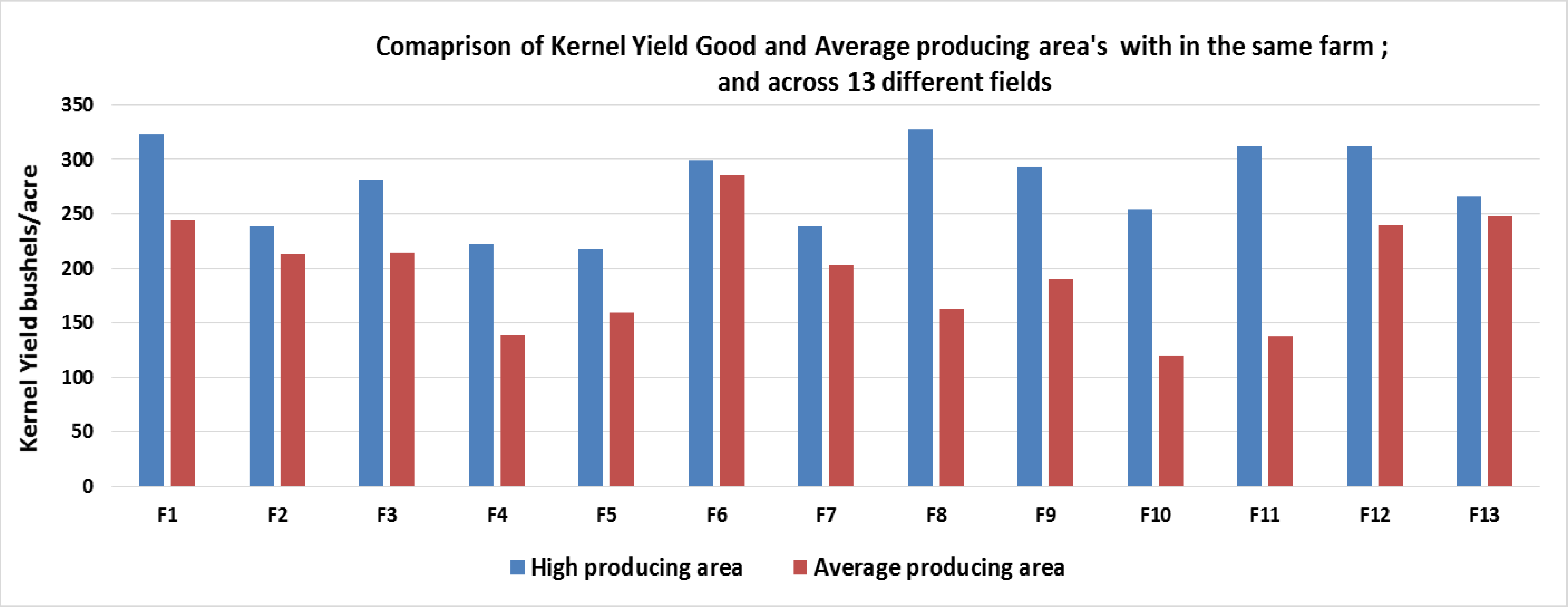
- 210.94 - 377.40 (0.00 ac)
- 203.24 - 210.94 (0.00 ac)
- 196.44 - 203.24 (0.00 ac)
- 188.46 - 196.44 (0.00 ac)
- 176.86 - 188.46 (0.00 ac)
- 155.36 - 176.86 (0.00 ac)
- 5.83 - 155.36 (0.00 ac)



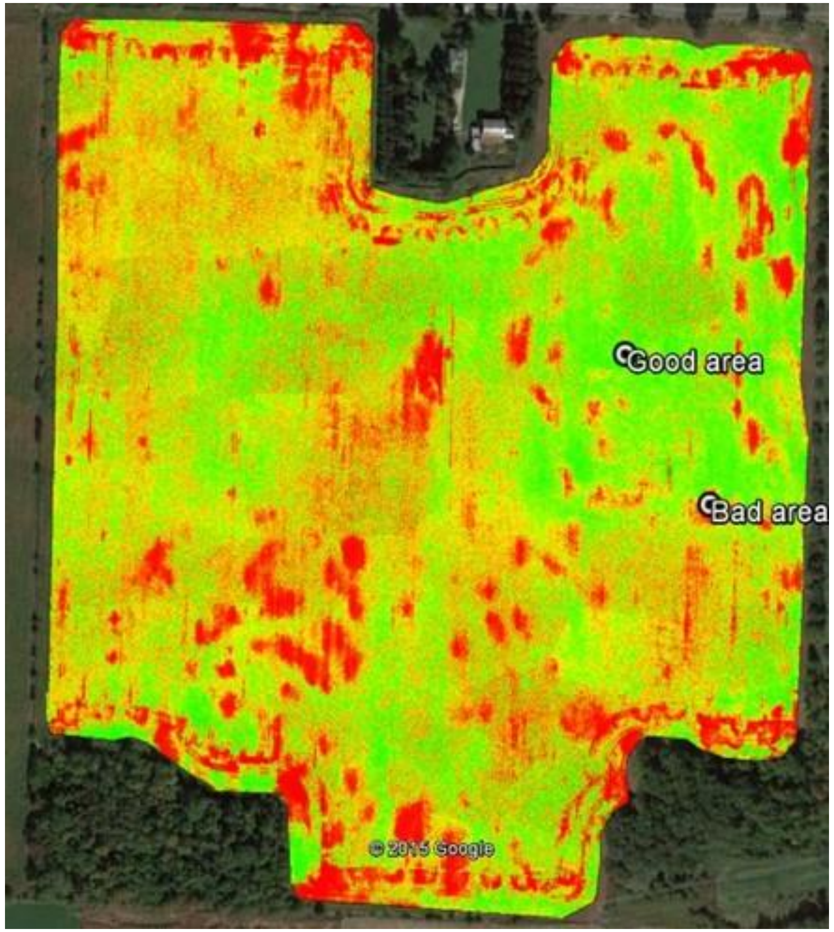
YIELDS BY LOCATION IN ONE PASS

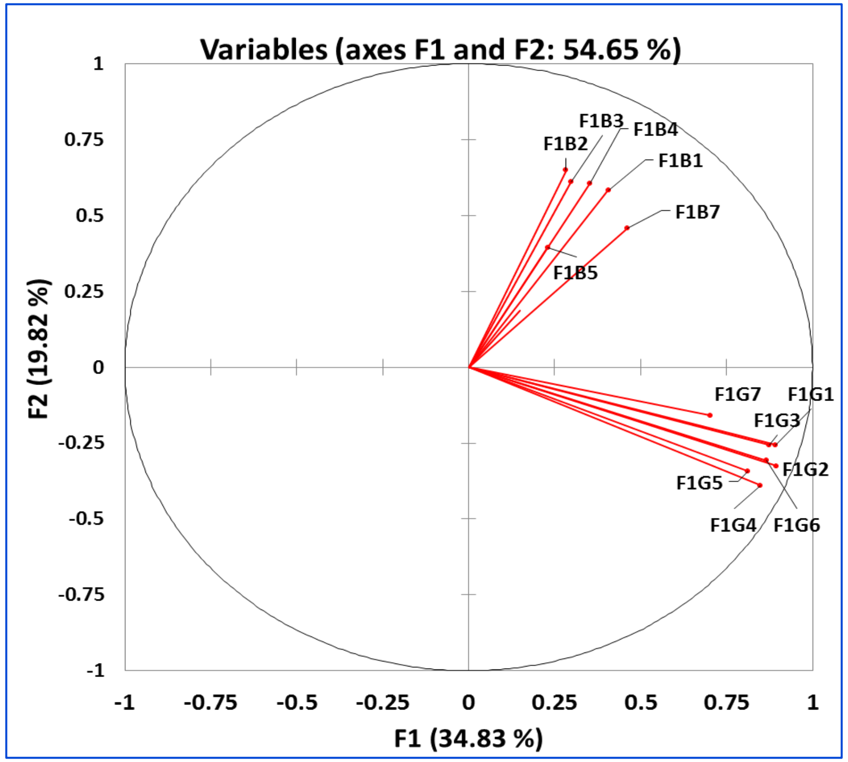


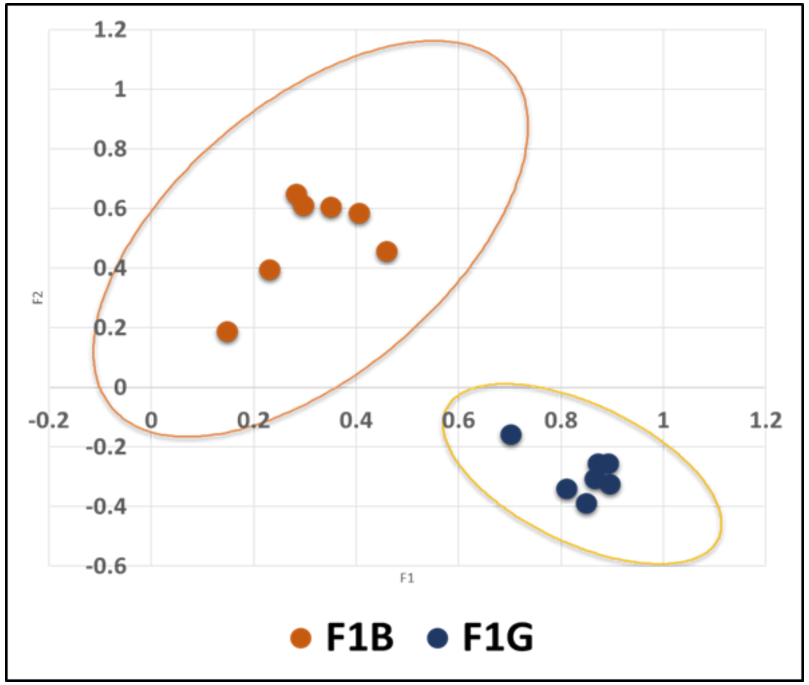
CORN YIELDS FORM 13 FIELDS



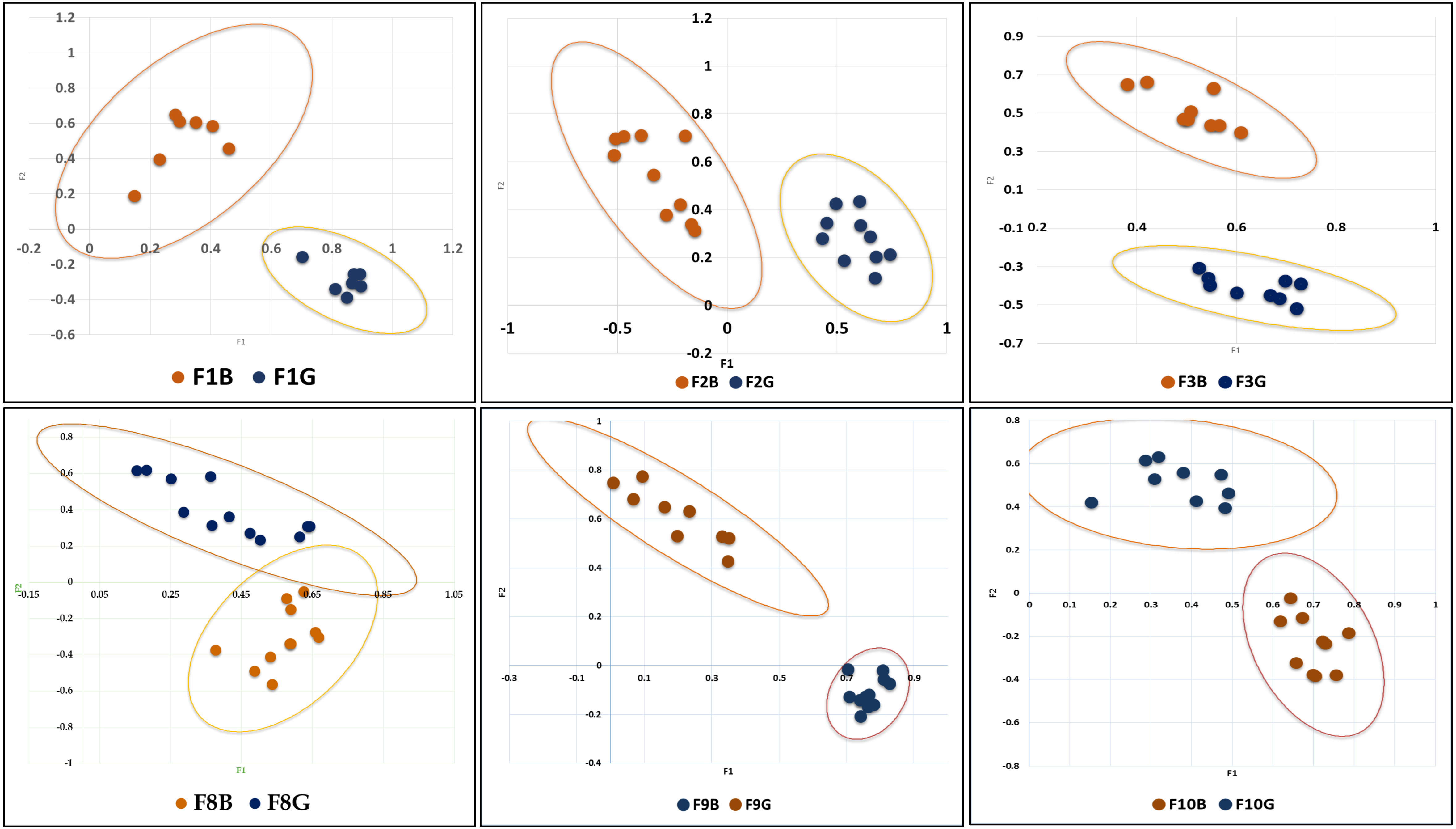
Diversity of Microbial community from the corn Sap collected from High and low producing Sites with in the same field-F1G and F1B

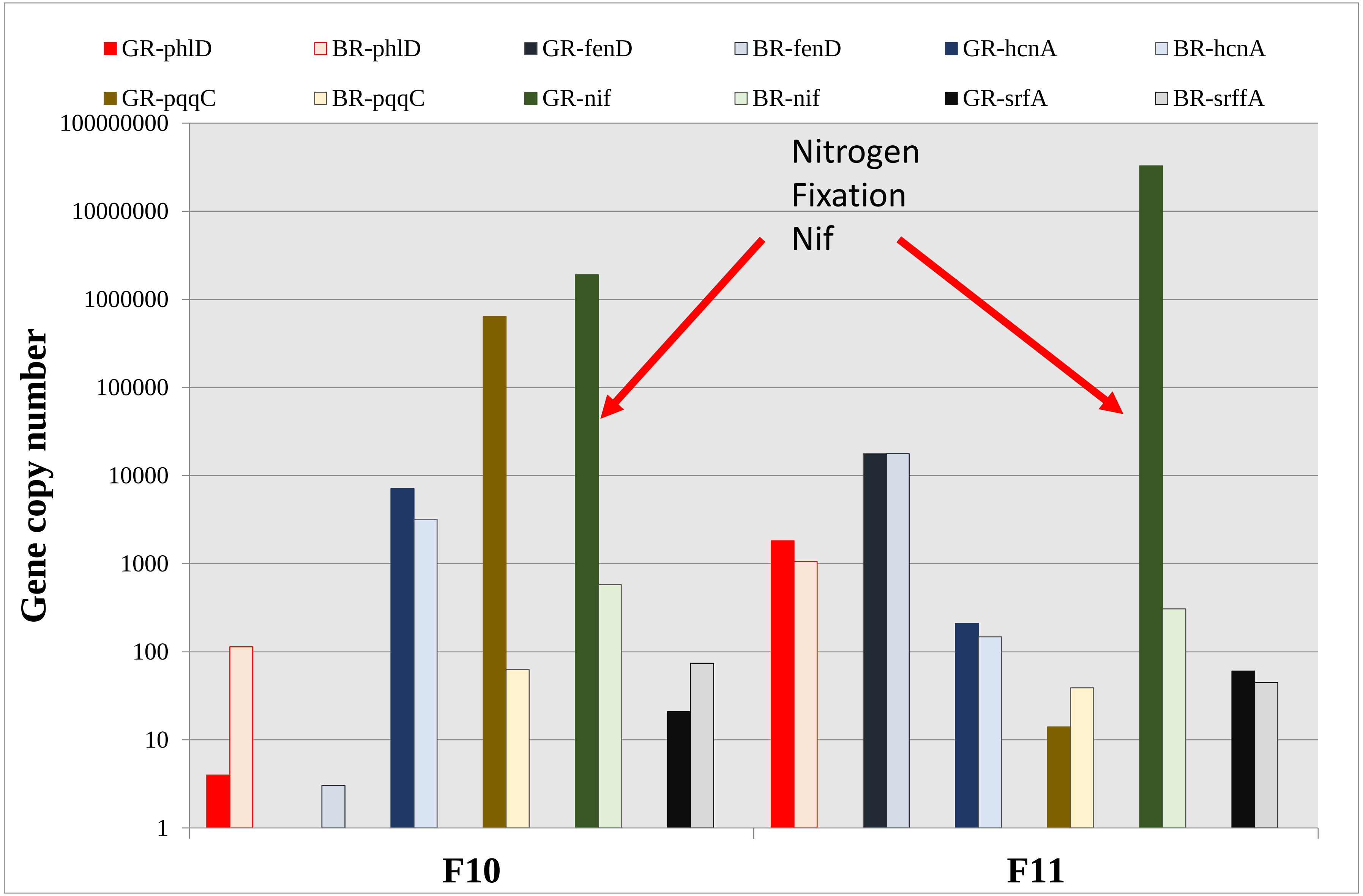






Diversity of Corn Sap microbiome in High and Average producing Sites





Functional gene analysis on DNA extracted from corn roots from high and average producing sites of two different corn fields

List of Factors showed significant direct correlation to the yield

Fields with high total CFU

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

High *Pseudomonas*

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

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

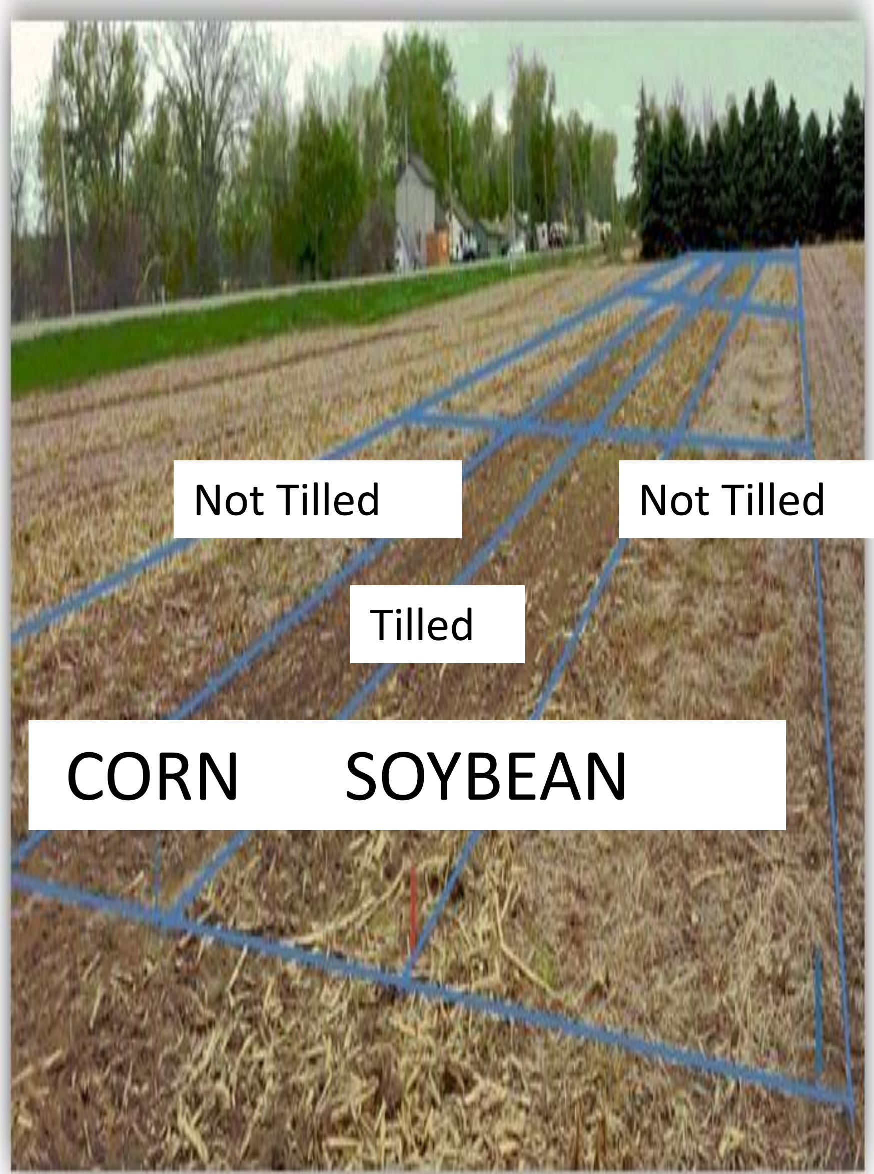
Rank	Factors
1	General Fertility Index (GFI)
2	% K
3	K/Mg Ratio
4	Nitrate Nitrogen
5	pH
6	CEC meq/100g
7	Saturation (%) P
8	Soluble salts ms/cm
9	Calcium (Ca)

All Fields with high *Rhizobium*

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

High gram positives population

GFI Rhizosphere	0.698
Nitrate Nitrogen	0.631
% K	0.704
K/Mg Ratio	0.567

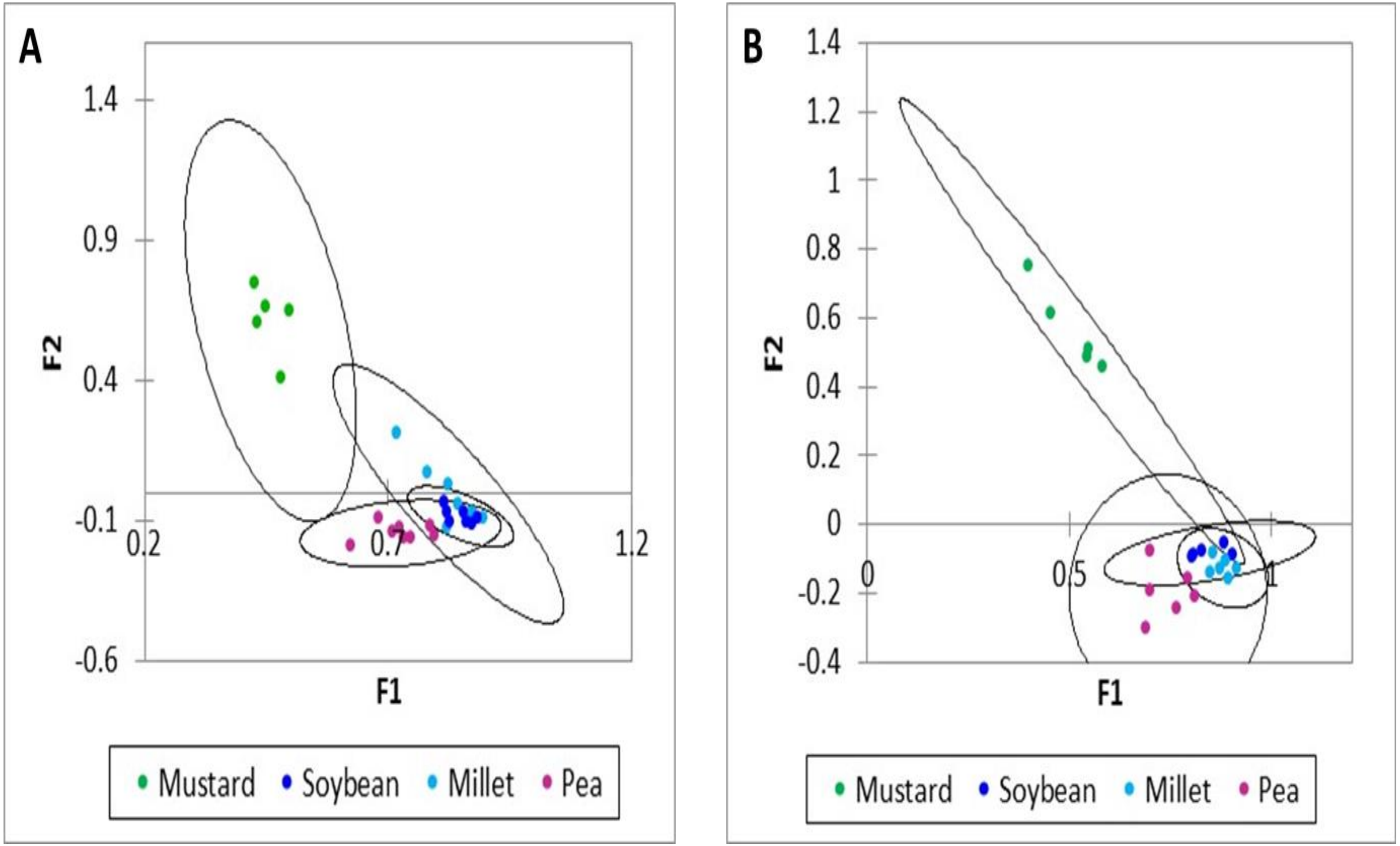


GREEN MANURE ROTATIONS IN TILLED AN NON TILLED SITES AT THE GLENNEY FARM

YIELDS OF CORN ON TILLED (T) AND NO-TILLED (NT) SITES FOLLOWING GREEN MANUR ROTATIONS

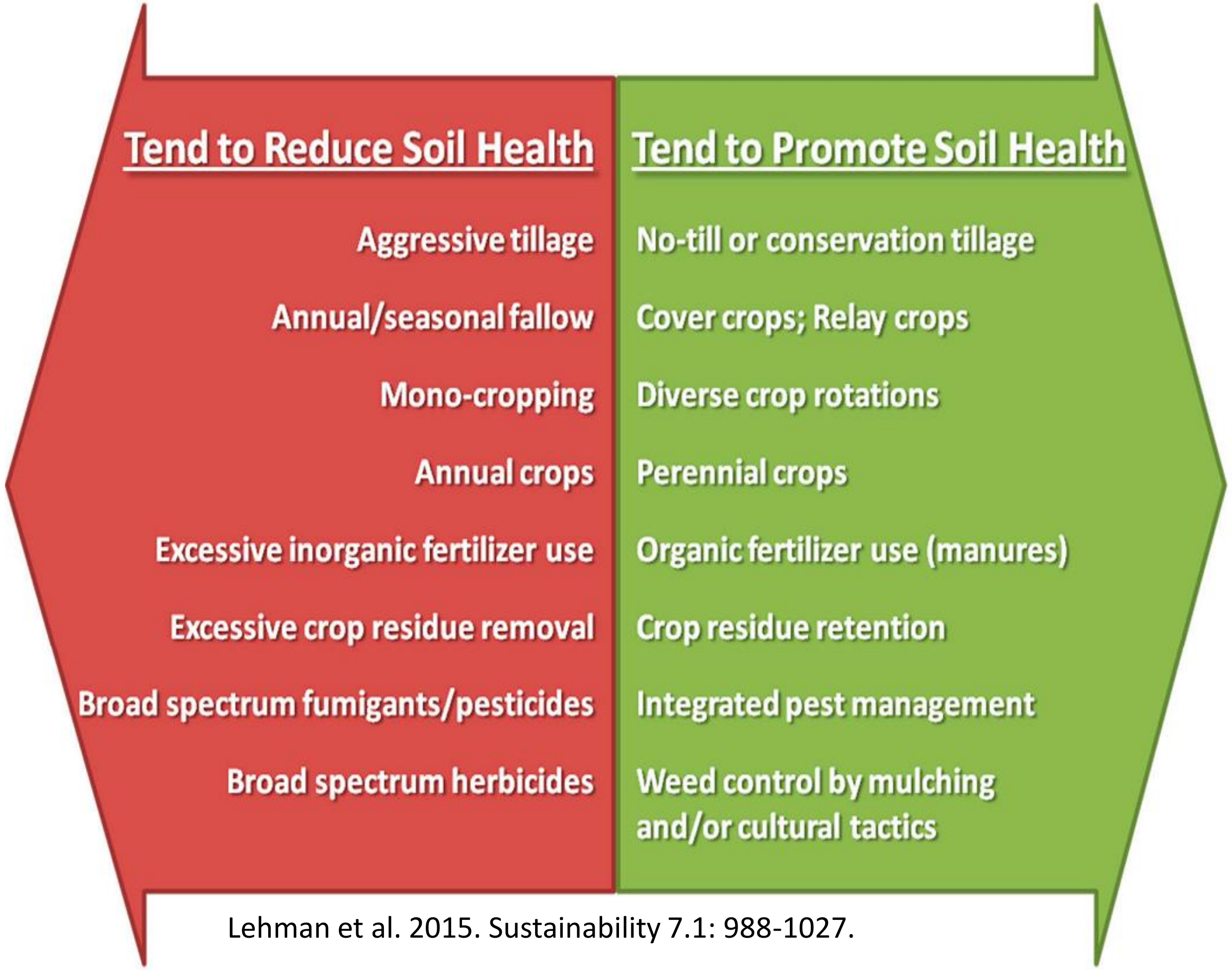
Plots	Sites	Kg/50 plants	Weight calculated to 15 % MC	Yield Kg/ Acre	Yield lbs / Acre	Bushels per acre	% change over control (Soybean)
G - NT	Mustard	10.0	11.7	7503	16544	295.4	-2.6
	Peas	10.3	12.1	7744	17076	304.9	0.5
	Millet	11.1	13.0	8324	18354	327.8	8.1
	Soybeans	10.2	12.0	7703	16984	303.3	0
G - T	Mustard	10.3	12.1	7752	17098	305.3	4.7
	Peas	11.3	13.2	8477	18691	333.8	14.5
	Millet	10.0	11.8	7537	16619	296.8	1.8
	Soybeans	9.8	11.6	7401	16320	291.4	0

TRFLP OF BACTERIA COMMUNITIES IN CORN SAP FORM PLANTS GROWN IN NO-TILLED (A) AND TILLED SOILS AFTER GREEN MANURE ROTATIONS

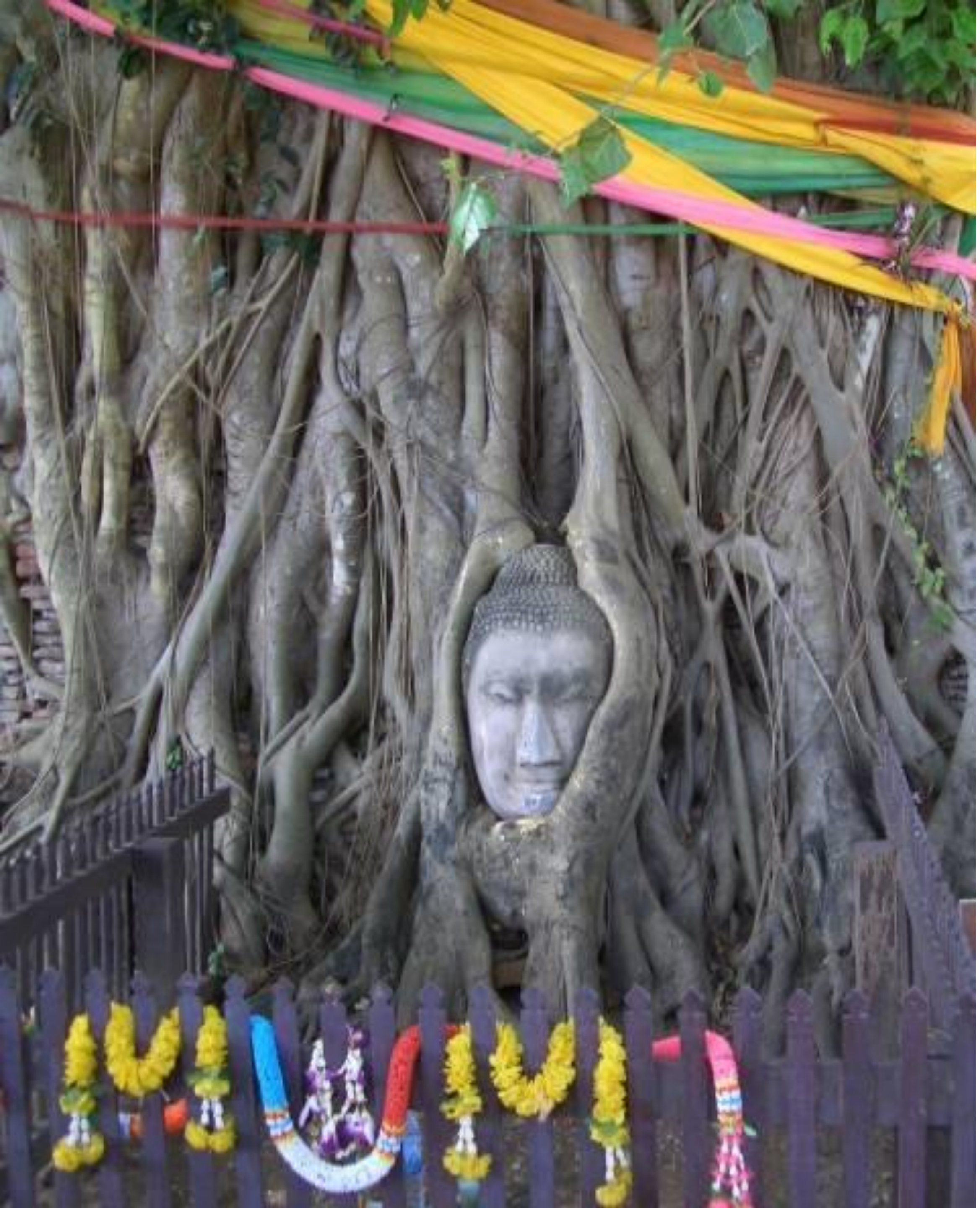


CONCLUSIONS AND SUMMARY

1. Good news - at minimum 1/3 of soils support excellent productivity – 1/3 underperform –WHY? And HOW to FIX IT?
2. Soil Health in agriculture will be crop specific and will be related to crop performance
3. Microbiology has a large role in soil and crop health – but it will be difficult to measure impact as many factors regulate populations and these we don't yet fully understand



Lehman et al. 2015. Sustainability 7.1: 988-1027.



The Next Green Revolution will Emerge from Underground

Acknowledgements

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A&L Growing Forward 2 AAC agricultural adaptation council Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada OntarioGenomicsInstitute