Influence of Diverse Compost Products on Soil Physicochemical Properties and Soil Microbial Communities in Potato Production System

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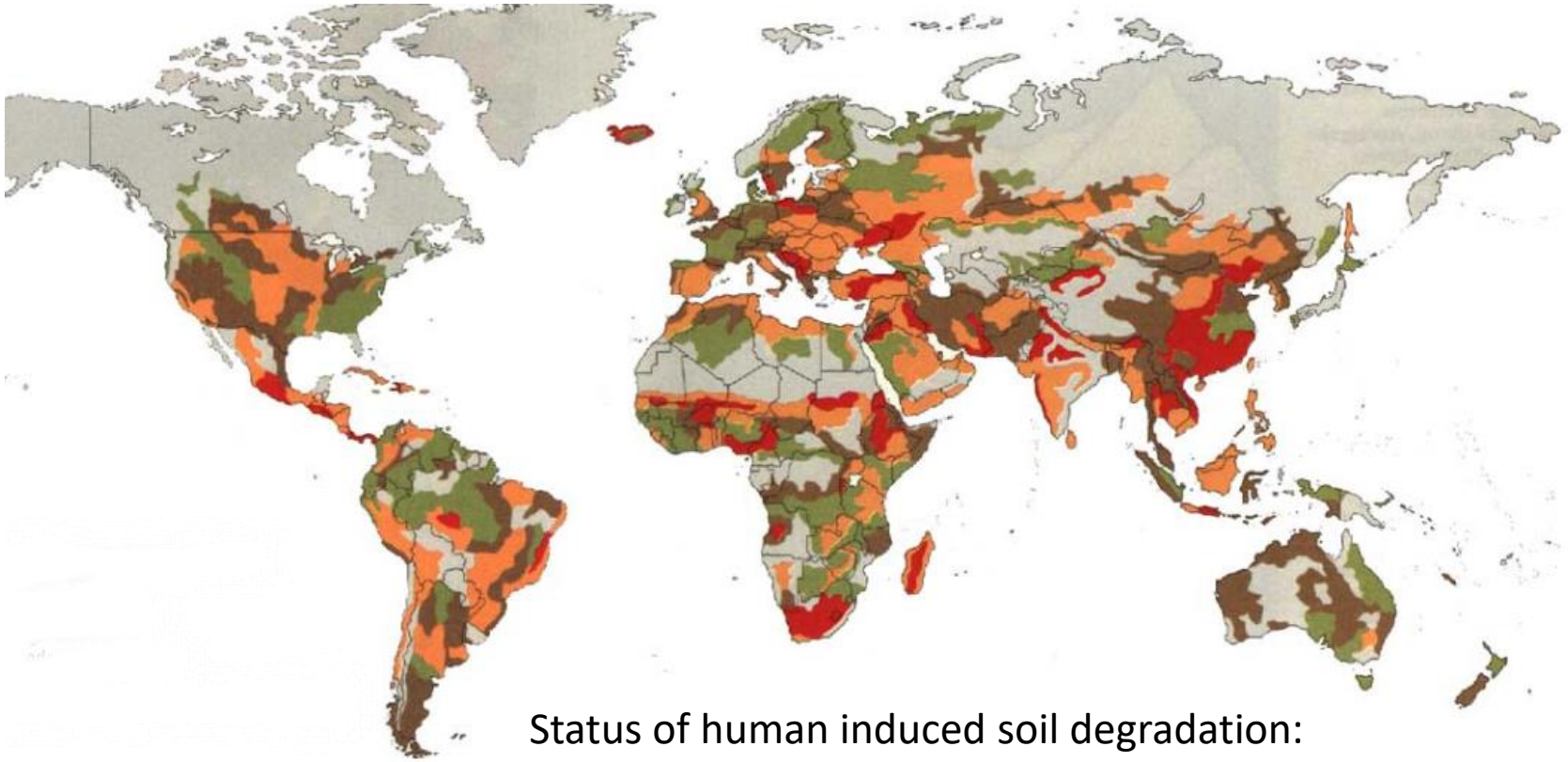
Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

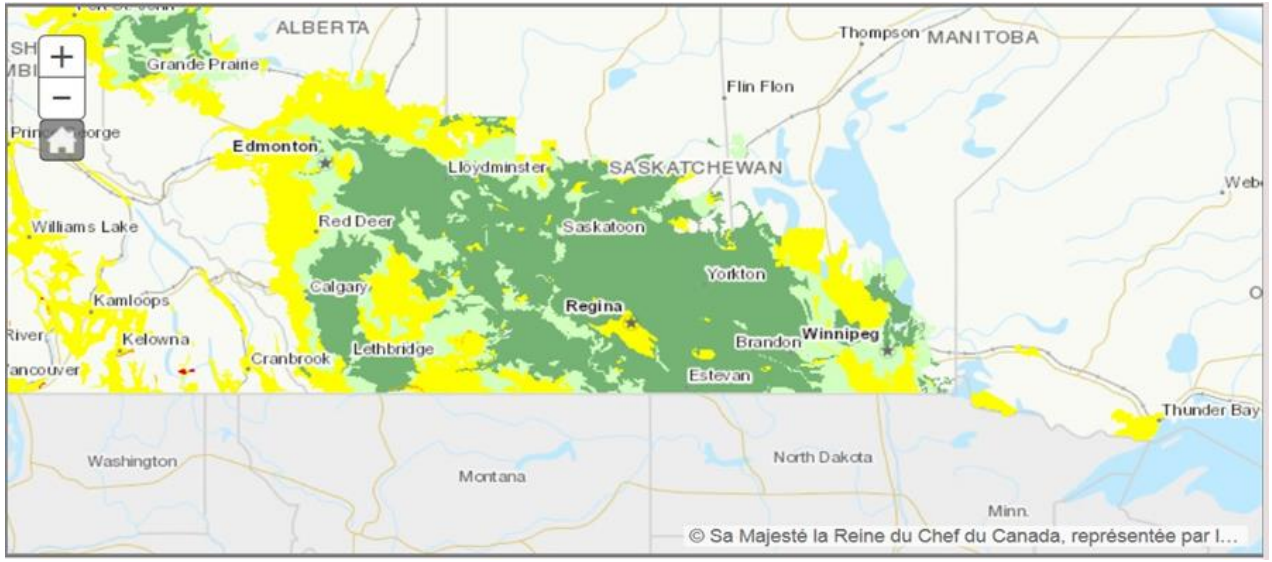
Global Agricultural Soil Degradation

- **52%** of the land used for agriculture is moderately or severely affected by soil degradation
- In last 100 years: **1/3 of the top soil ground was lost**.
- It takes at least **500 years** for 2.5 centimeters of topsoil to regenerate.
- Land Degradation over the next 25 years may reduce global food production by up to **12%** resulting in an increase of, as much as, **30%** of world food prices

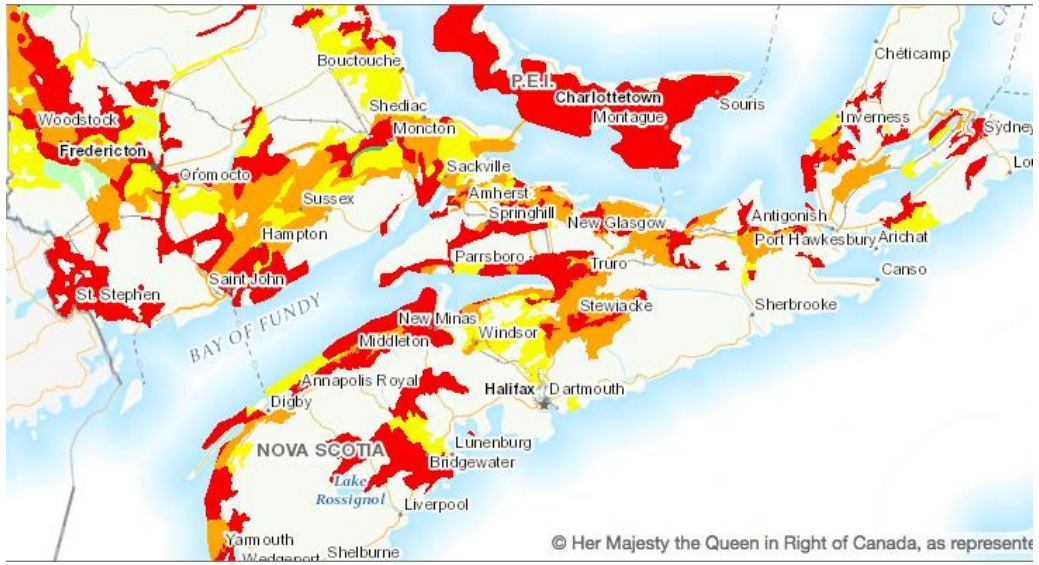


Cumulative soil organic matter change from 1981 to 2011

West Canada



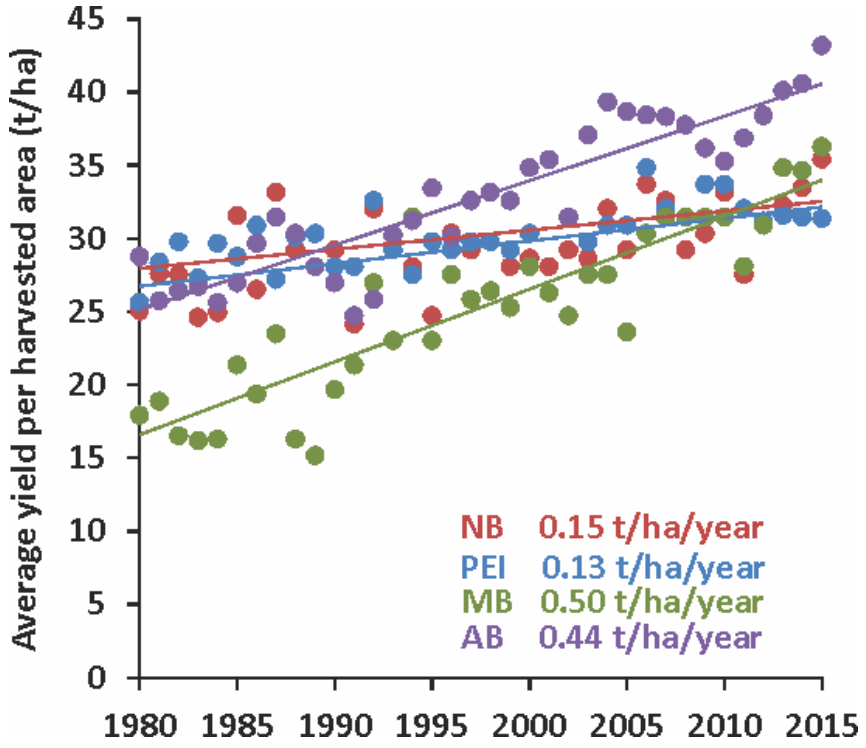
East Canada



http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/soil-and-land/soil-organic-matter-indicator/?id=1462905651688

Productivity Challenge

Average potato yield (Statistics Canada) per year



Factors reducing potato yields:

- Rolling landscape, shallow soils
- Bare soil exposed in spring and fall
- Frequent soil tillage (*e.g.* for planting, hilling, harvest)
- Minimal crop residue returned to soil
- Short (mostly 2 year) rotations
- Intensive practices = decline in soil quality

Compost to the rescue?

Potential benefit of compost

- Improves soil quality
- Increased SOM, aggregation, water holding capacity
  - Decreased bulk density
- Reduced severity of soil borne diseases
- More predictable nutrient availability than raw manure
- Can increase potato yields – water holding capacity
- Increases microbial community diversity

Objective

The objective was to determine the effect of diverse compost products on soil quality, potato productivity and bacterial and fungal community diversity.

SSOC: Municipal Source Separated Organic Compost
FPMC: Forestry and Poultry Manure Compost
MSC: Marine with Shelfish Compost
MC: Poultry Manure Compost
FRC: Forestry Residue Compost
Control (no compost application)

Compost product properties

Property	FRC Forestry residues	FPMC Forestry waste and poultry manure	MSC Marine with shellfish	MC Poultry manure	SSOC Source separated organics
C:N	59	26	23	23	15
DM (%)	42	58	68	52	48
Ash (%)[1]	55	73	75	52	55
pH	7.2	7.6	7.7	7.4	7.7
C (%)[1]	23	15	18	25	25
N (%)[1]	0.4	0.6	0.8	1.1	1.8
NH_4-N:NO_3-N	>8.3	1.0	1.4	>5.2	2.5

[1]dry matter basis

Material and Methods

Experimental site and sampling

- Site located at AAFC, Fredericton, NB
- 2014: barley crop; 2015 & 2016: potato crop
- October 2014 and 2015: 45 tonnes ha^{-1} (dry weight basis)
- Randomized complete block design with four replicates
- Six treatments: Control (no compost application), 5 compost products
- Soil sampling in 2015 & 2016:

May (spring pre-plant) and September (fall post-harvest)

Material and Methods - measurements

Desired Soil Improvement	Assessment
#1 Increased storage and supply of plant nutrients	▪ Cation exchange capacity (CEC) ▪ Soil pH ▪ Extractable nutrients ▪ Plant Nutrient Uptake
#2 Improved soil structure	▪ Bulk density (BD) ▪ Resistance to penetration ▪ Water-holding capacity (WHC) ▪ Permeability
#3 Improved organic matter quality and quantity	▪ Soil organic carbon (SOC) ▪ Particulate organic matter (POM) ▪ Microbial biomass carbon (MBC) ▪ Permanganate oxidizable carbon (POX)
#4 Reduced soil borne disease	▪ Tuber disease assessments
#5 Improved productivity	▪ Potato tuber yield, size and quality
#6 Improved soil microbiome diversity	▪ Next-generation sequencing of bacterial and fungal communities

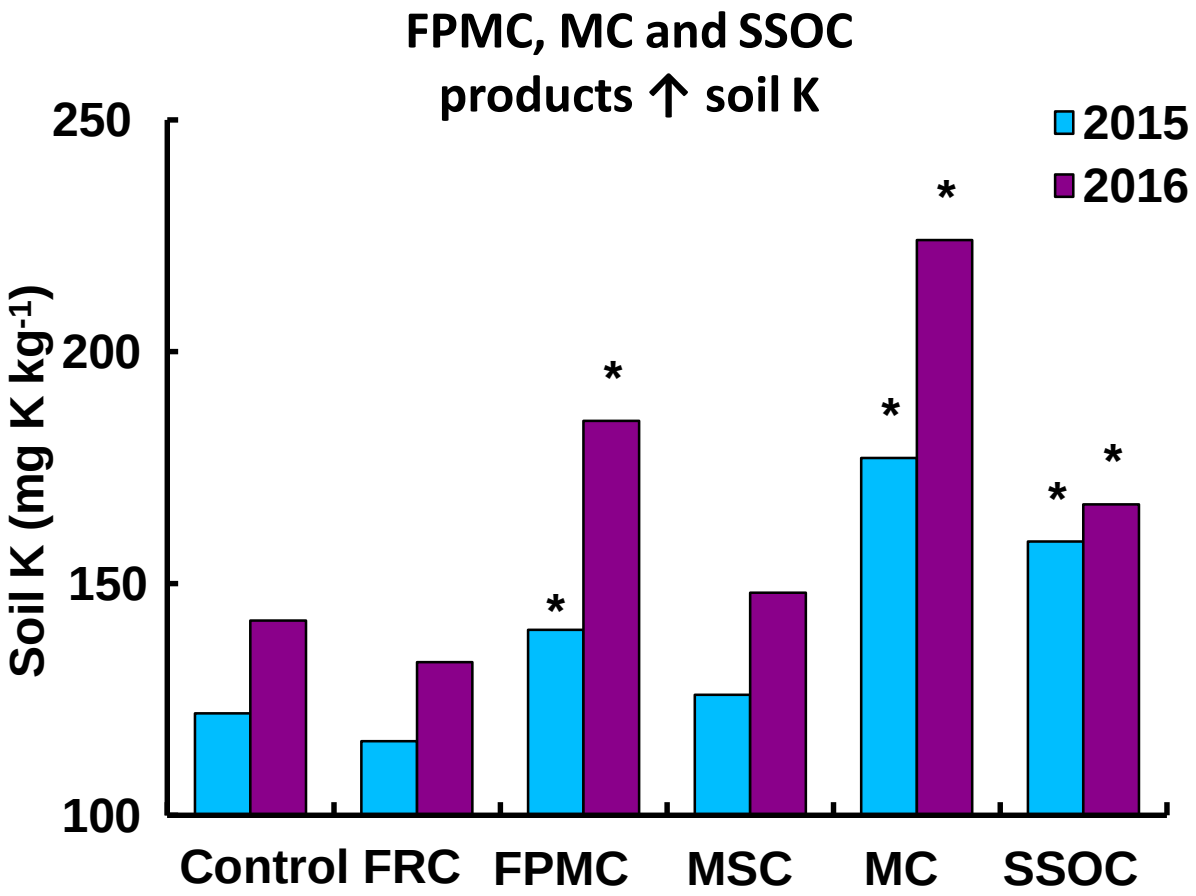
Compost products & soil nutrients

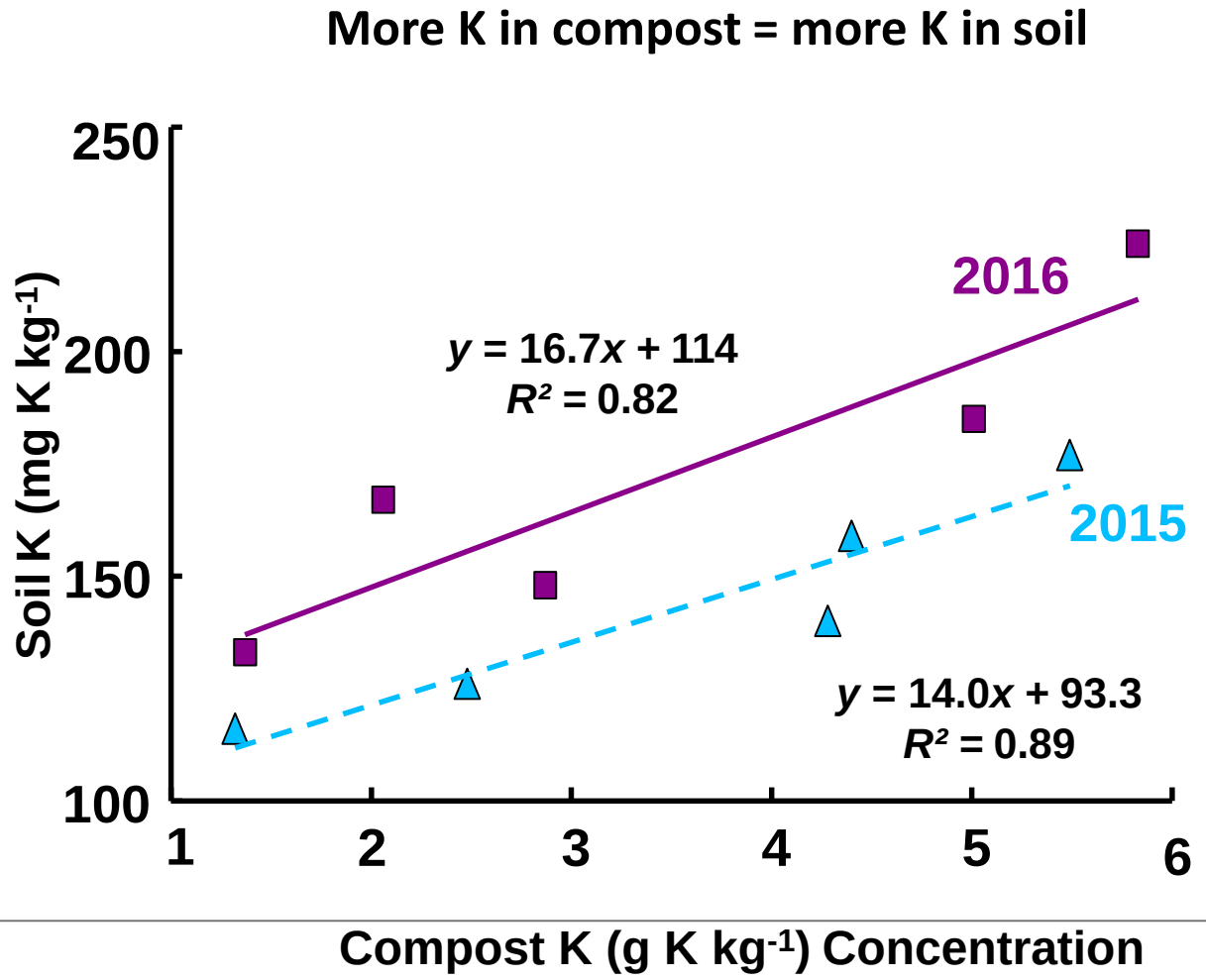
Benefit #1 Compost Increased the Ability of Soil to Supply Plant Nutrients

- In both years, compost increased
  - Extractable K, Ca, Mg, S, B, Zn and Mn
  - Soil pH
  - Total soil N
- There were significant differences among treatments
- Evidence of N immobilization with FRC product

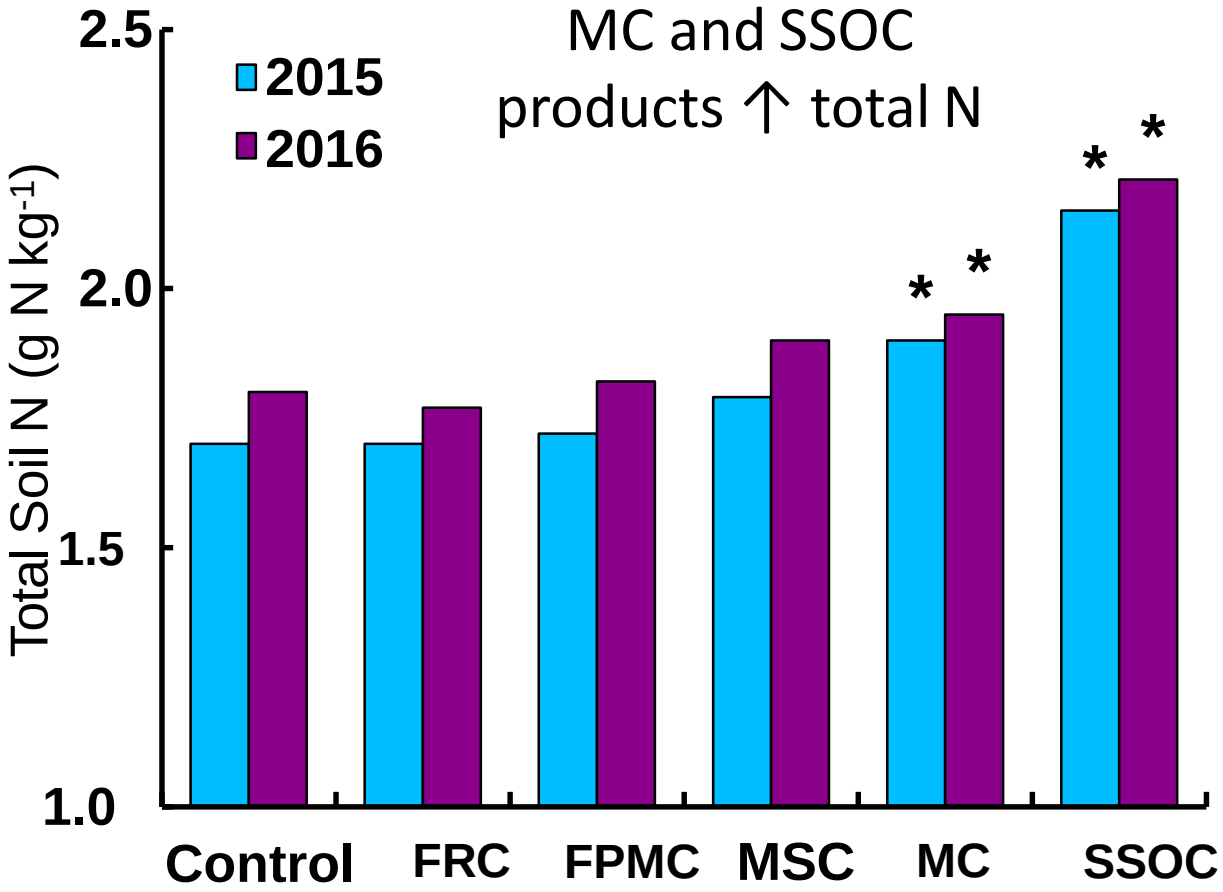
Wilson et al. 2018. Soil. Sci. Am. J. 82:889-900

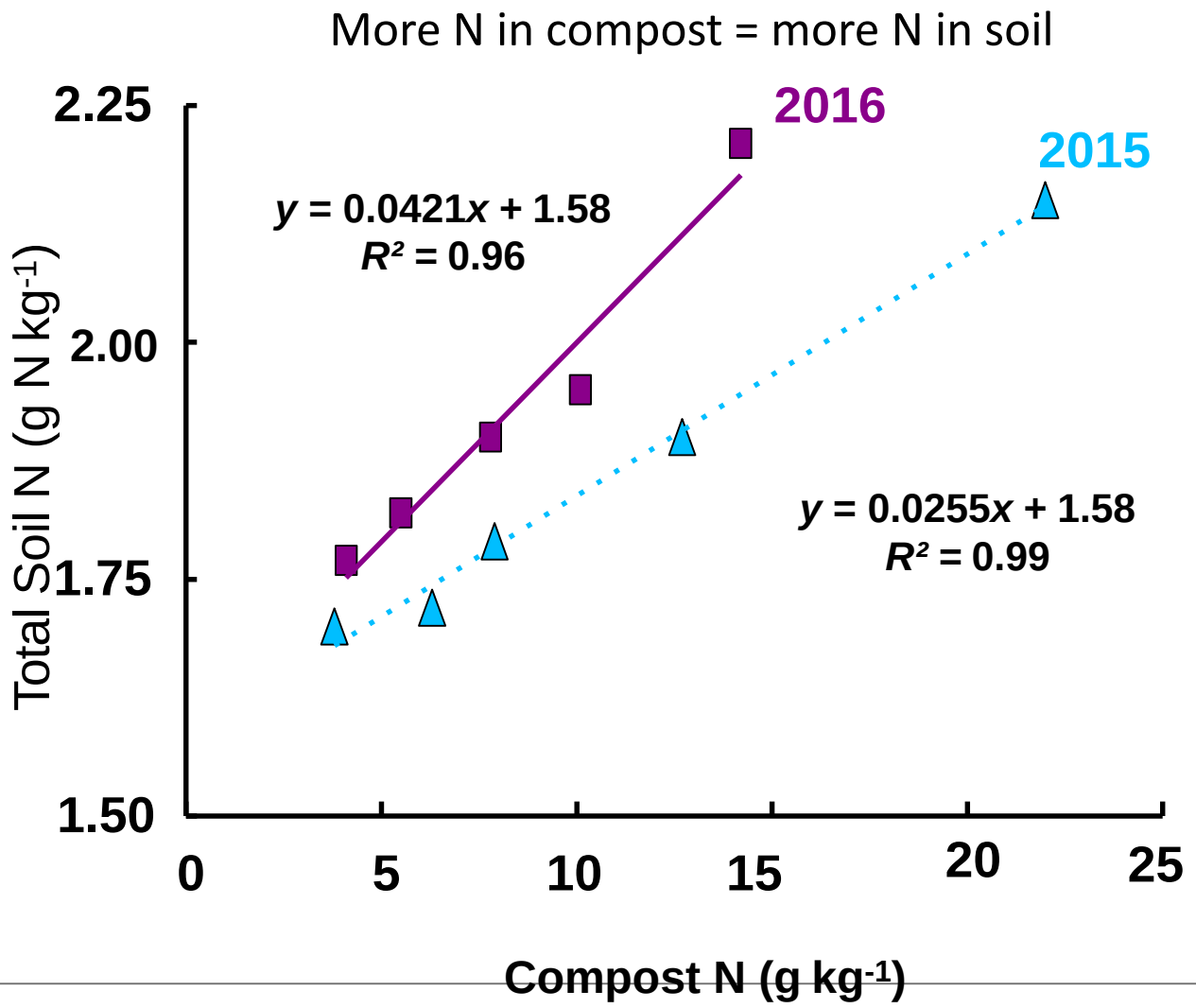
Soil extractable potassium (K)



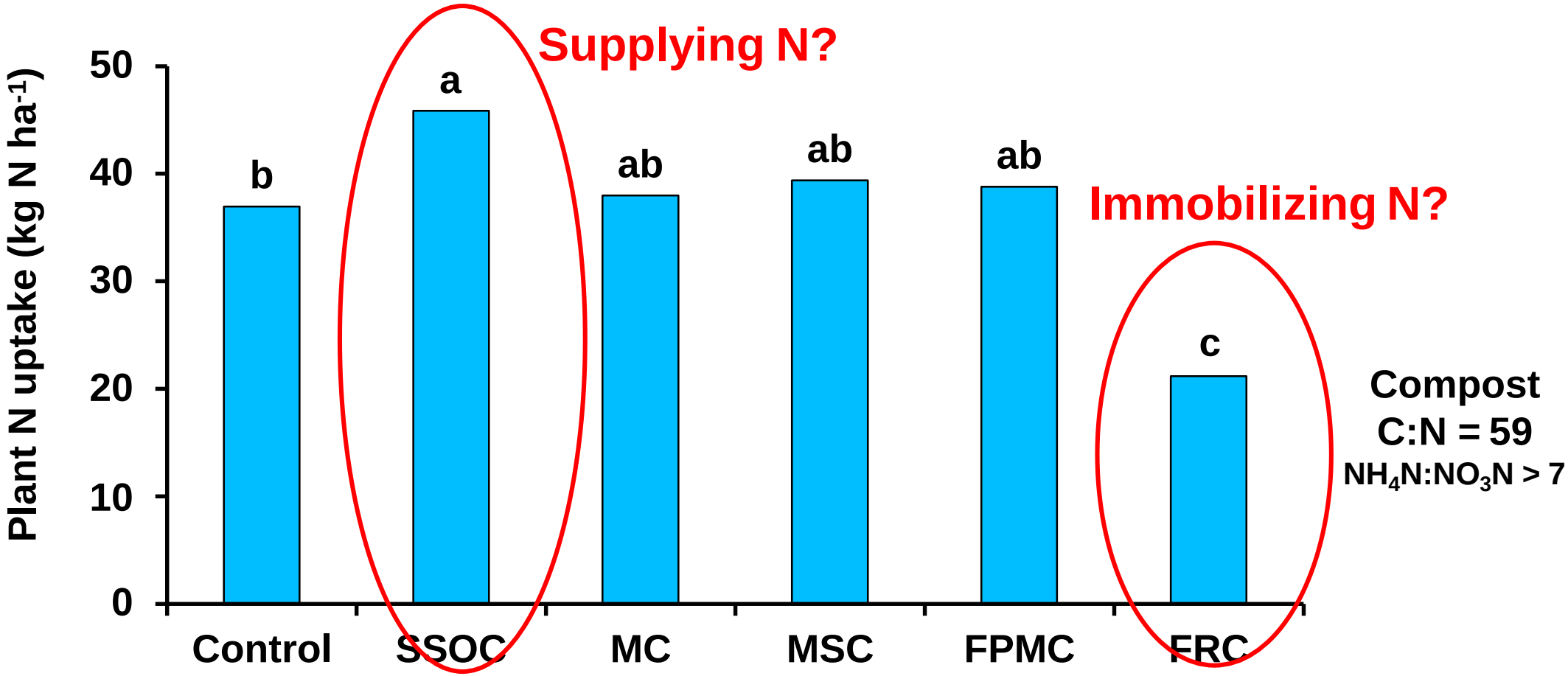


Soil total nitrogen (N)





Plant N uptake in 2015



Compost products & soil physical properties

Benefit #2: Compost improved soil structure and water-holding capacity

- Reduction in bulk density in both years
- Increase in permeability in 2015
- Increase in water content at field capacity in 2016
- Reduction in resistance to penetration at some depths in 2016
- Significant differences among compost treatments

Compost products & soil physical properties

Soil organic C improves soil structure: more C = more benefits

	Average C applied (tonnes ha^{-1} yr^{-1})	Bulk density 2015 (g cm^{-3})	Permeability 2015 (cm hr^{-1})	Field Capacity 2016 (g g^{-1})
Control	0	1.04	26.8	0.254
FPMC	7	1.02	34.7	0.257
MSC	8	1.03	30.5	0.251
FRC	11	0.96*	38.6*	0.260
MC	11	1.00	38.6*	0.256
SSOC	11	0.98*	43.5*	0.265*

Compost products & soil organic C

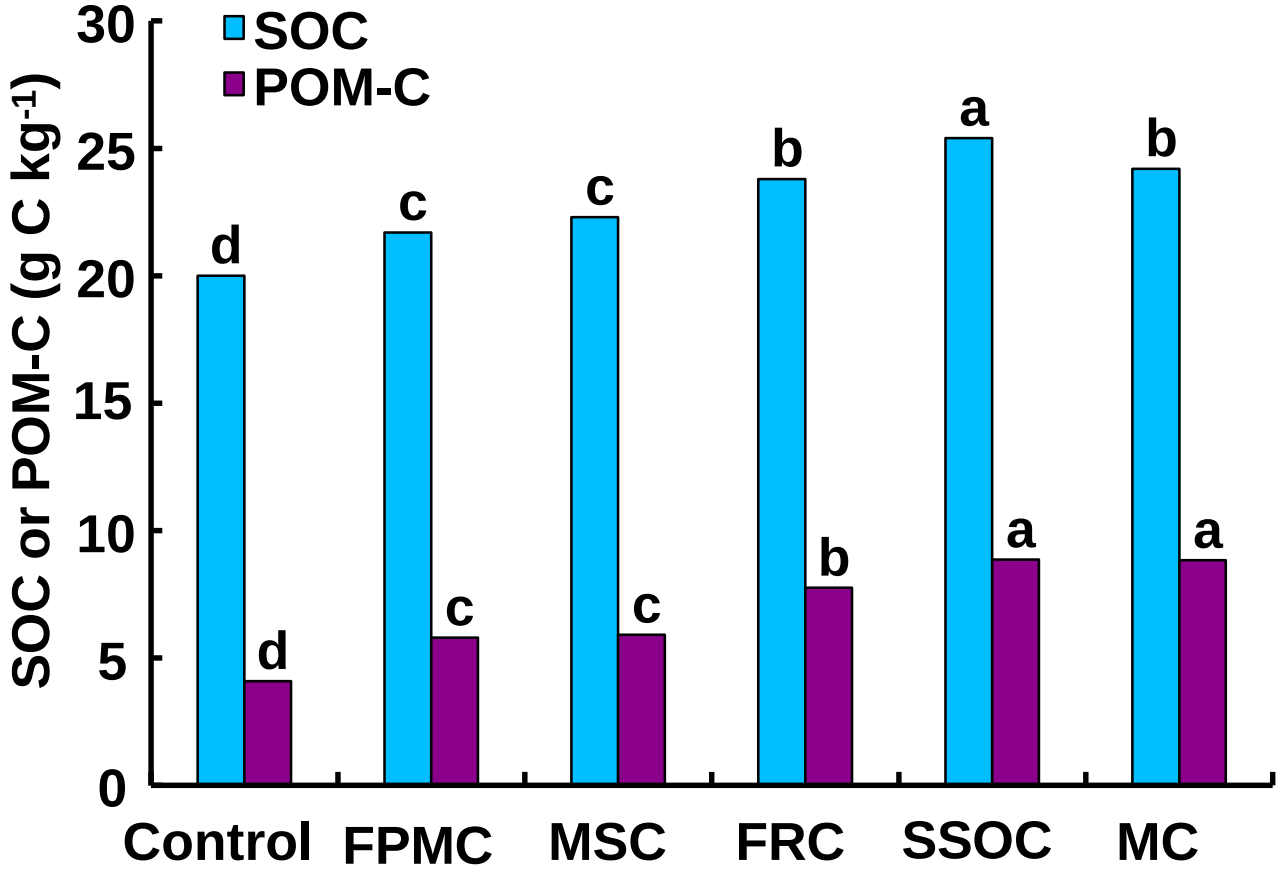
Benefit #3: Compost increased soil organic carbon (SOC) and carbon pools

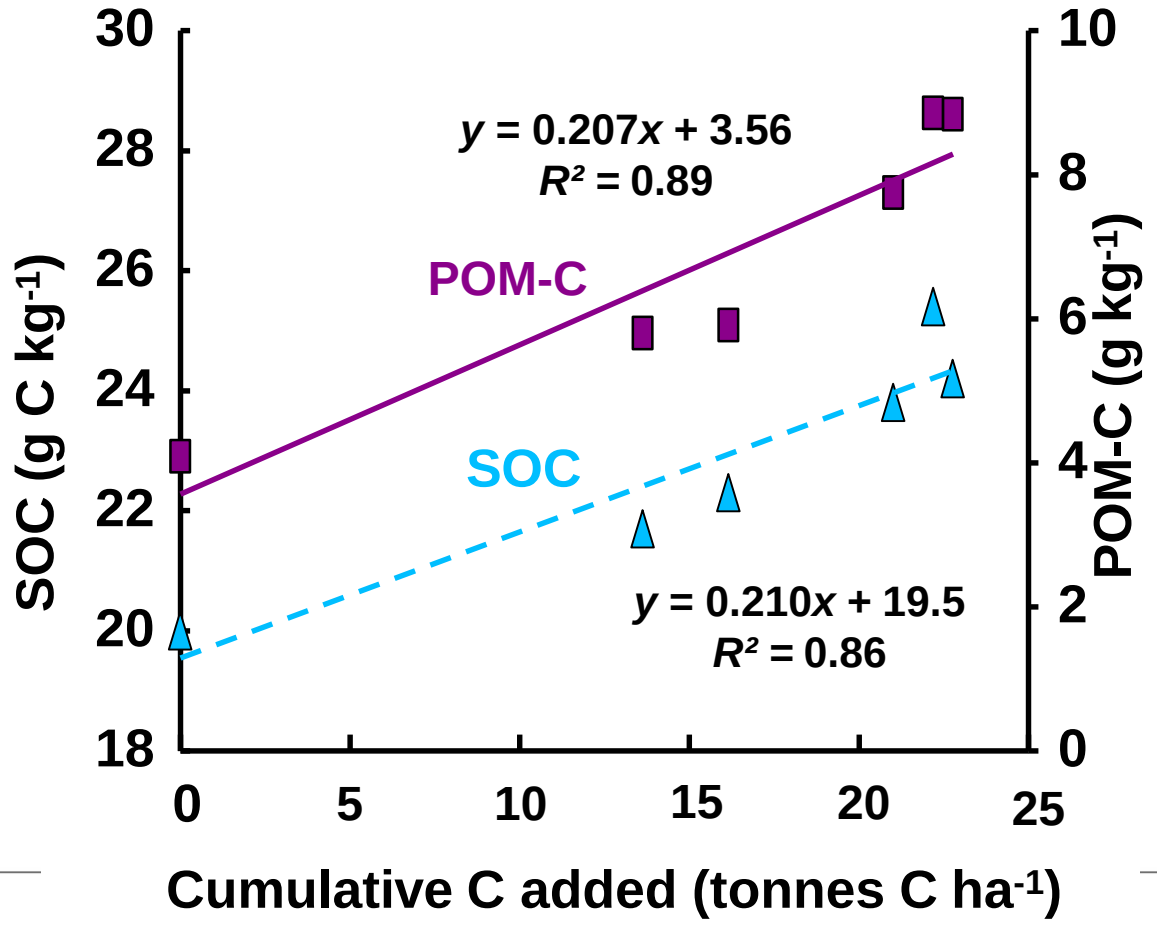
- Increase in SOC in soils treated with composts in both years
- In particular, an increase in active carbon (POX-C) and particulate organic carbon (POM-C) fractions

POM-C:

- A size fraction of soil organic matter between 0.053 and 2 mm in size
- Partially decomposed plant and organic material
- Many soil benefits:
  - Food/energy source for microorganisms
  - Soil structure builder
  - Nutrient source for plant growth

SOC and POM-C – Fall 2016

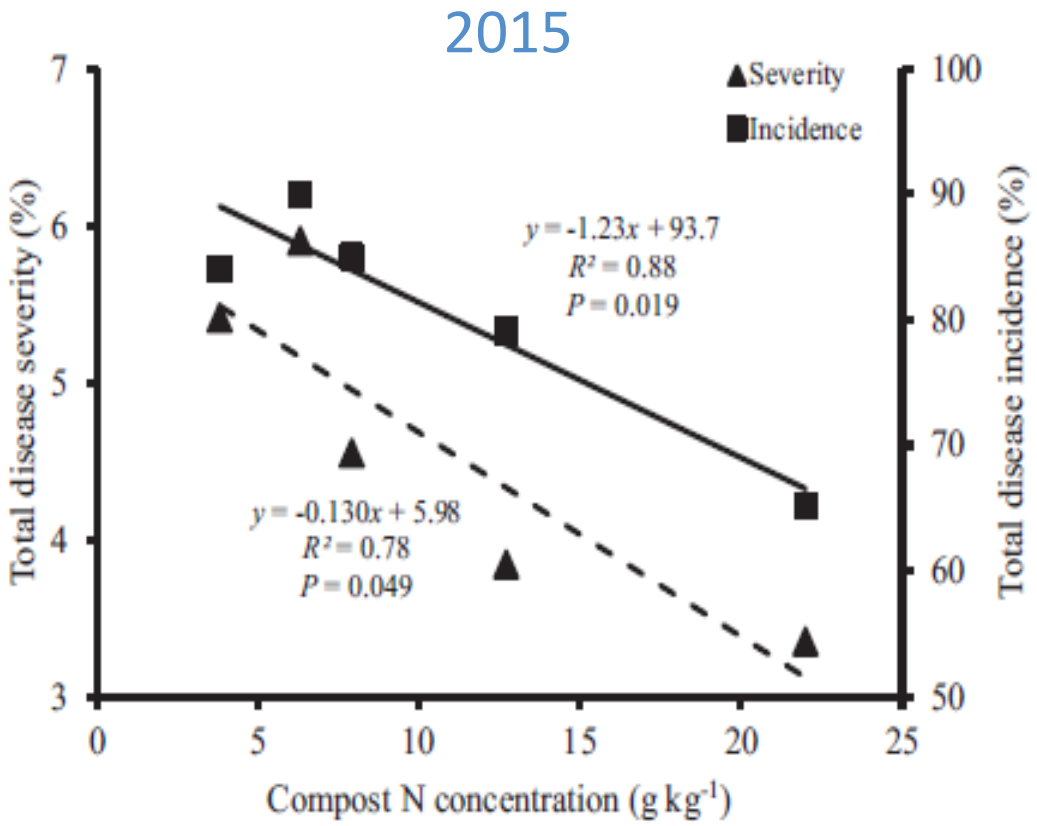




Compost products & disease suppression

Benefit #4: Compost reduced soil borne disease in some cases

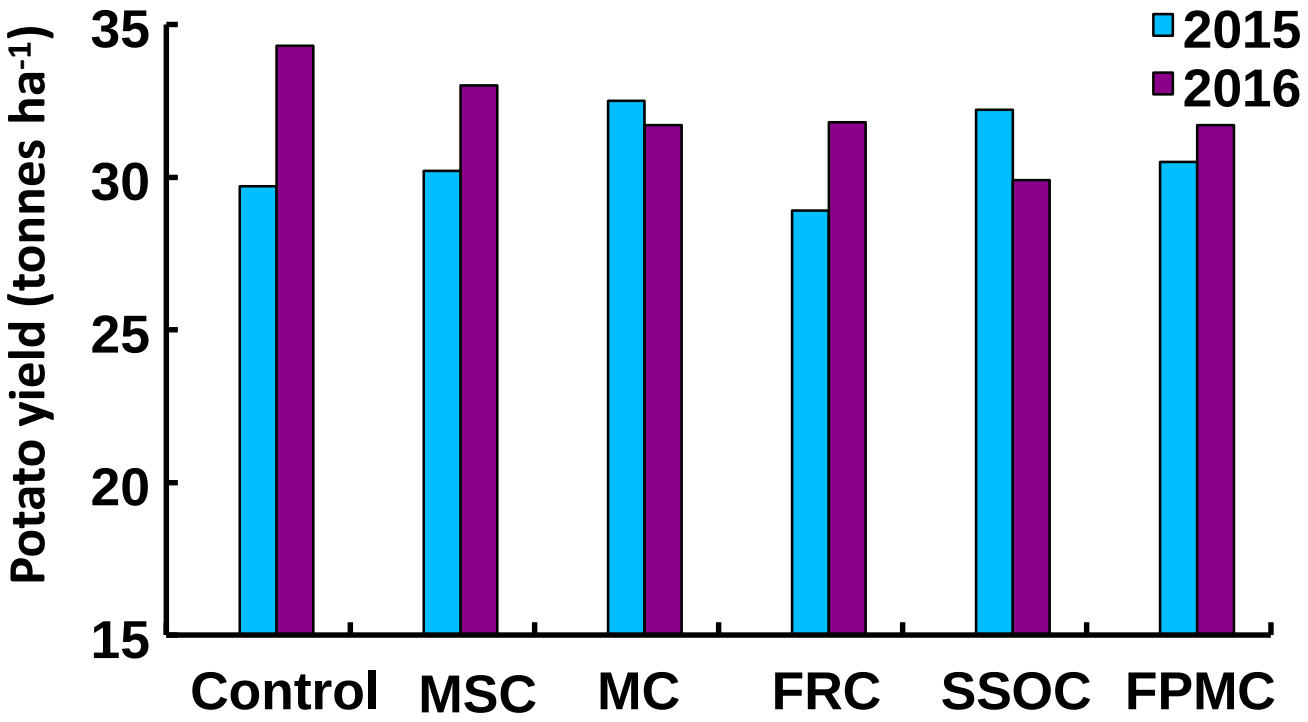
- Compost products did not result in greater disease severity or incidence of common scab, black surf, powdery scab, silver scurf compared to control
- Reduction in black scurf severity in MC-treated soils compared to control soils in 2016
- Overall disease suppression was inconsistent among treatments and between years.



Wilson et al. 2018. Compost Sci. Util. https://doi.org/10.1080/1065657X.2018.1432430

Compost products & potato yield

No effect on total potato yield!



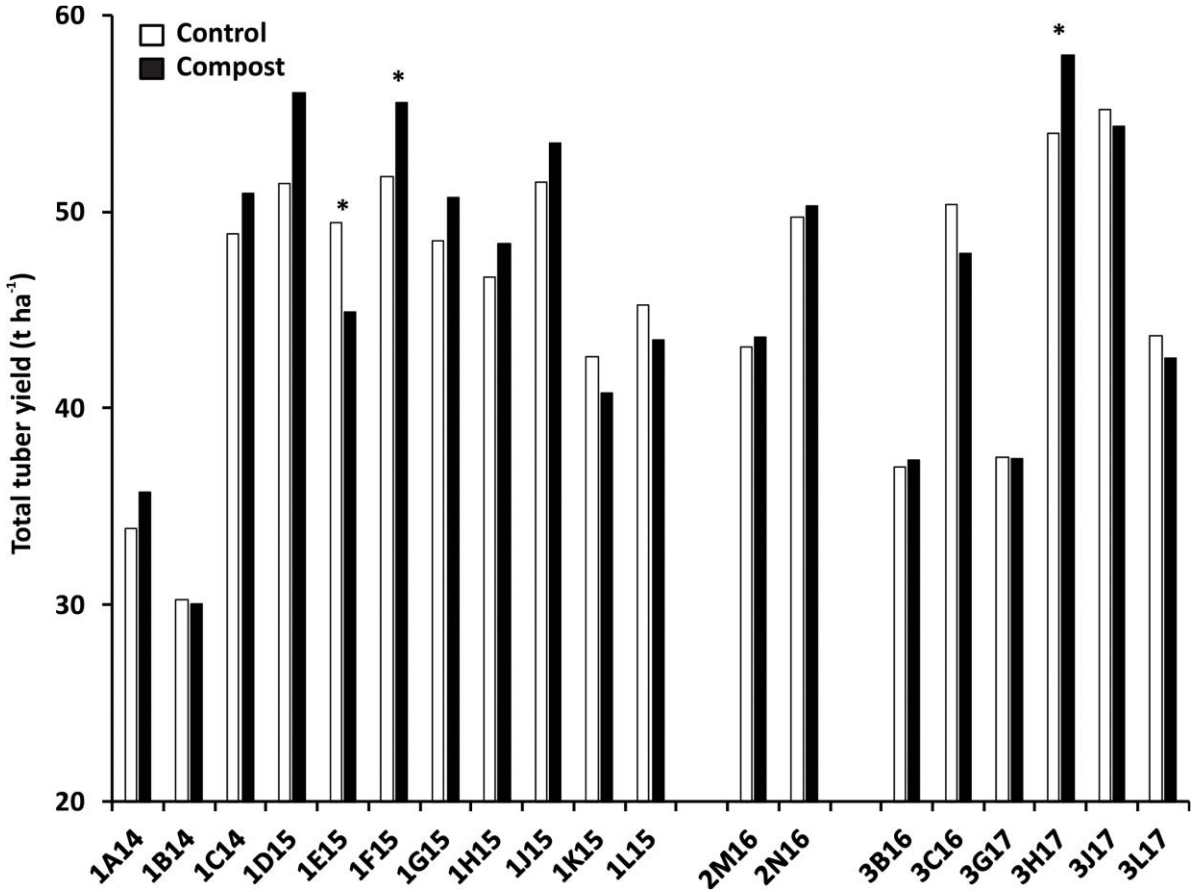
Too wet?

- 2015 growing season wetter than 30-year normal (1981-2010)
- Spring 2016
  - Rain following planting
  - Potato rot in several plots at harvest

Wilson et al. 2019. Am. Journal Potato Res.96:272–284

Compost products & potato yields

Potato yields in 19 site-years commercial potato fields in New Brunswick (Canada) with and without FPMC application (15 t ha^{-1}, wet weight)



Wilson et al. 2019. Soil Sci. Soc. Am. J. 82:889–900

Compost products and soil microbiome

- Three compost products:

SSOC: Municipal Source Separated Organic Compost
FPMC: Forestry and Poultry Manure Compost
FRC: Forestry Residue Compost
Control (no application)

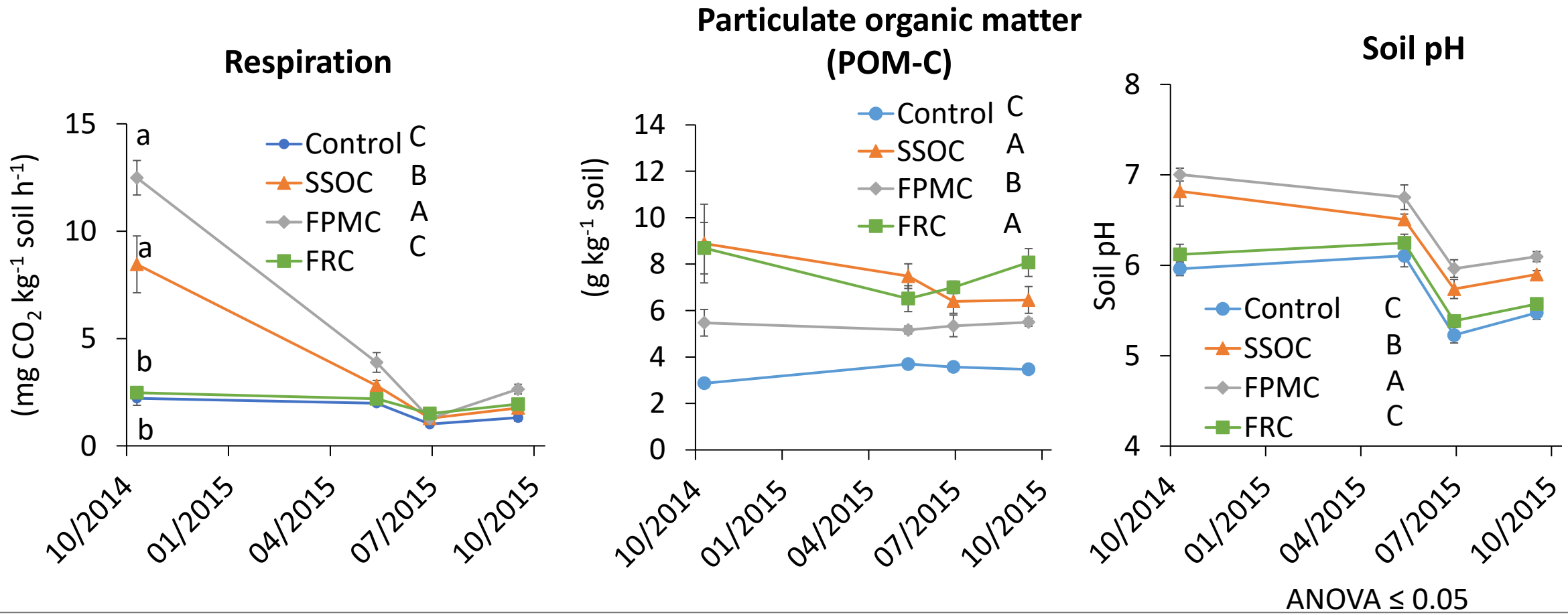
- Sampling done in October 2014 (after compost application), spring, summer and fall 2015

Bacterial and fungal community

- Amplicon-based metagenomics
  - 16S rRNA gene - bacteria
  - Ribosomal Internal transcribed spacer (ITS)
- Sequencing by Illumina MiSeq

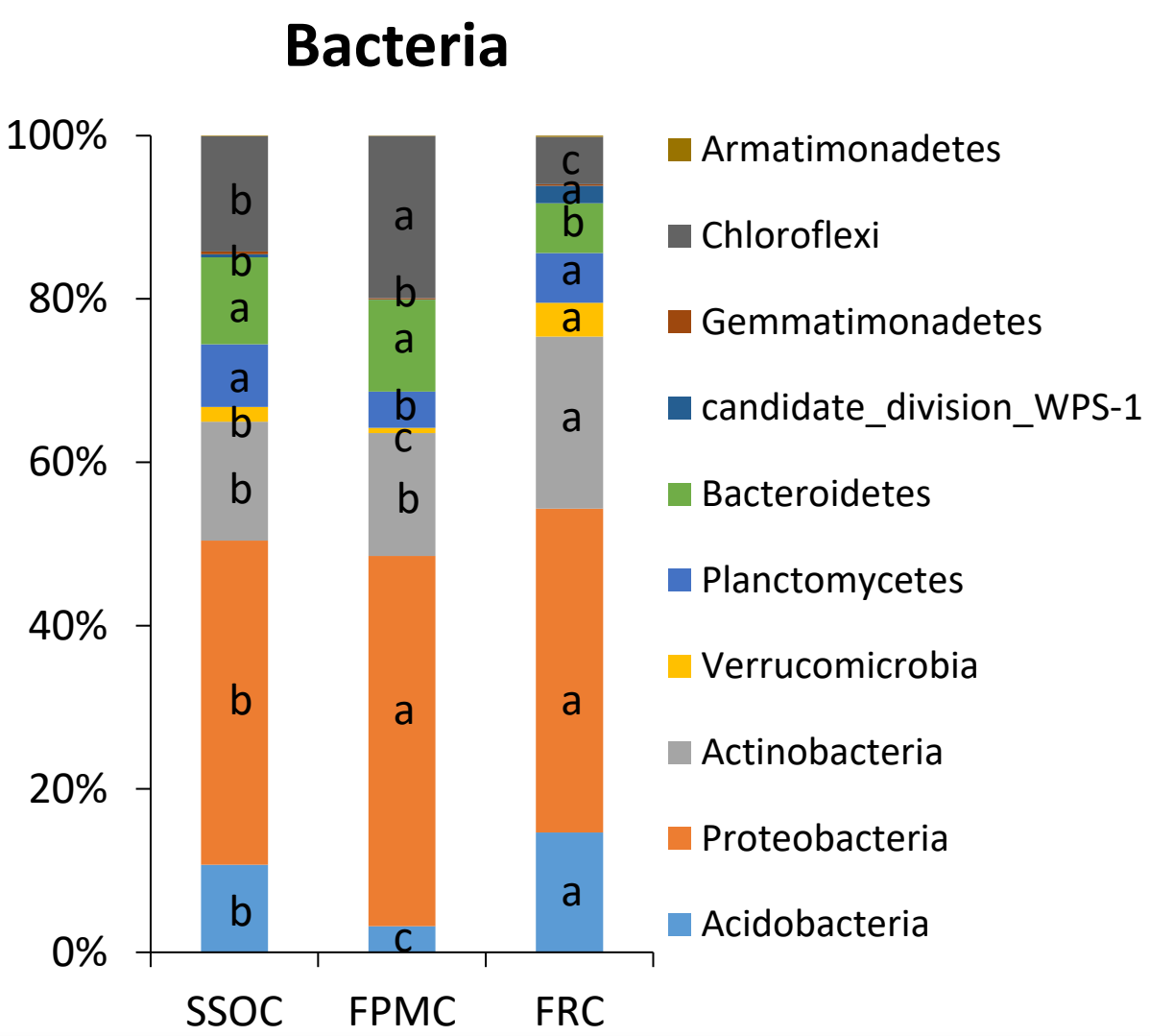
Results

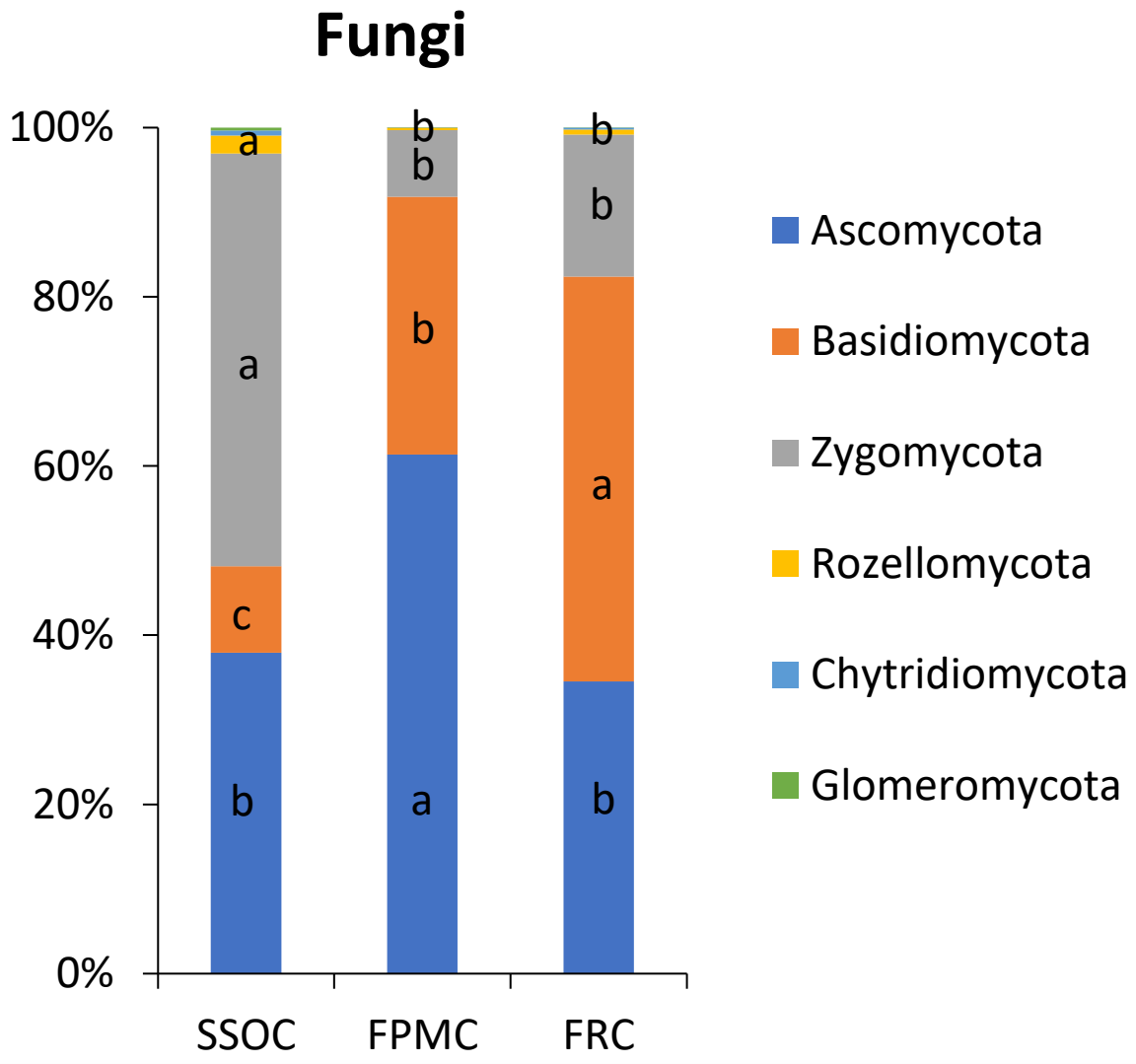
Compost changes key factors controlling abundance and diversity of soil microbiome



ANOVA ≤ 0.05

Results – Relative abundance of phyla in composts

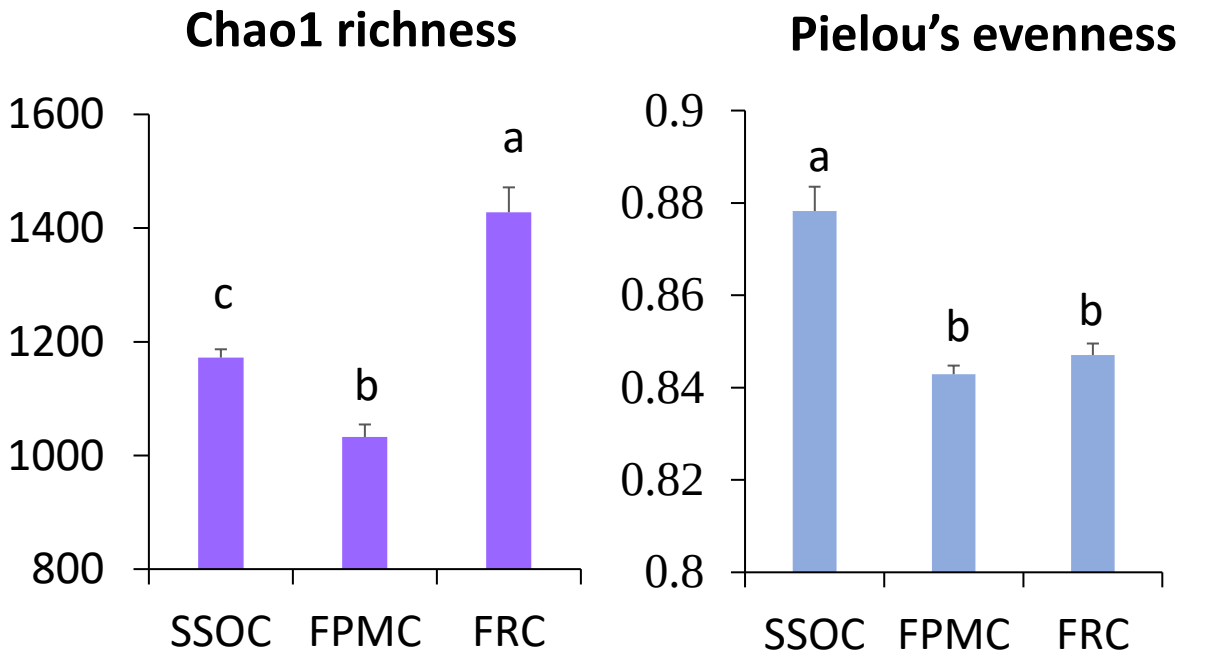




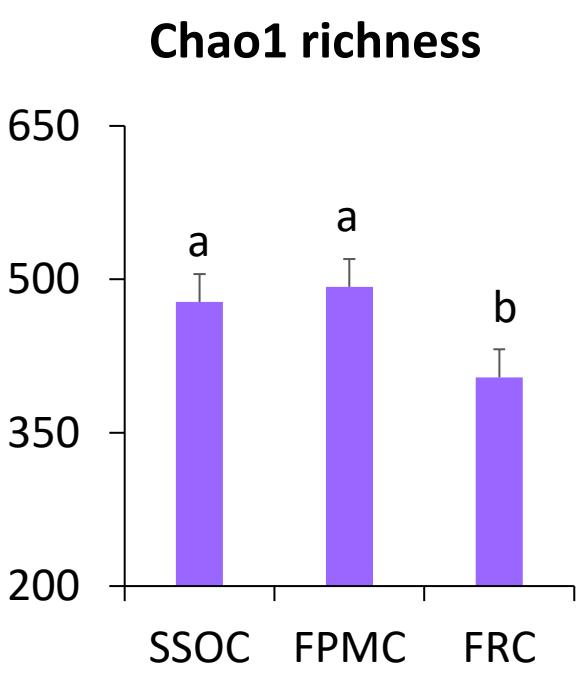
ANOVA ≤ 0.05

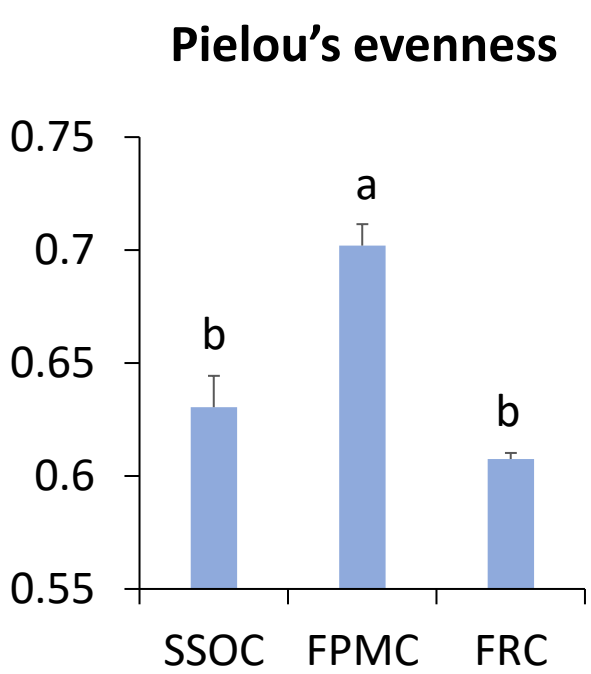
Results – biodiversity indices of composts

Bacteria



Fungi

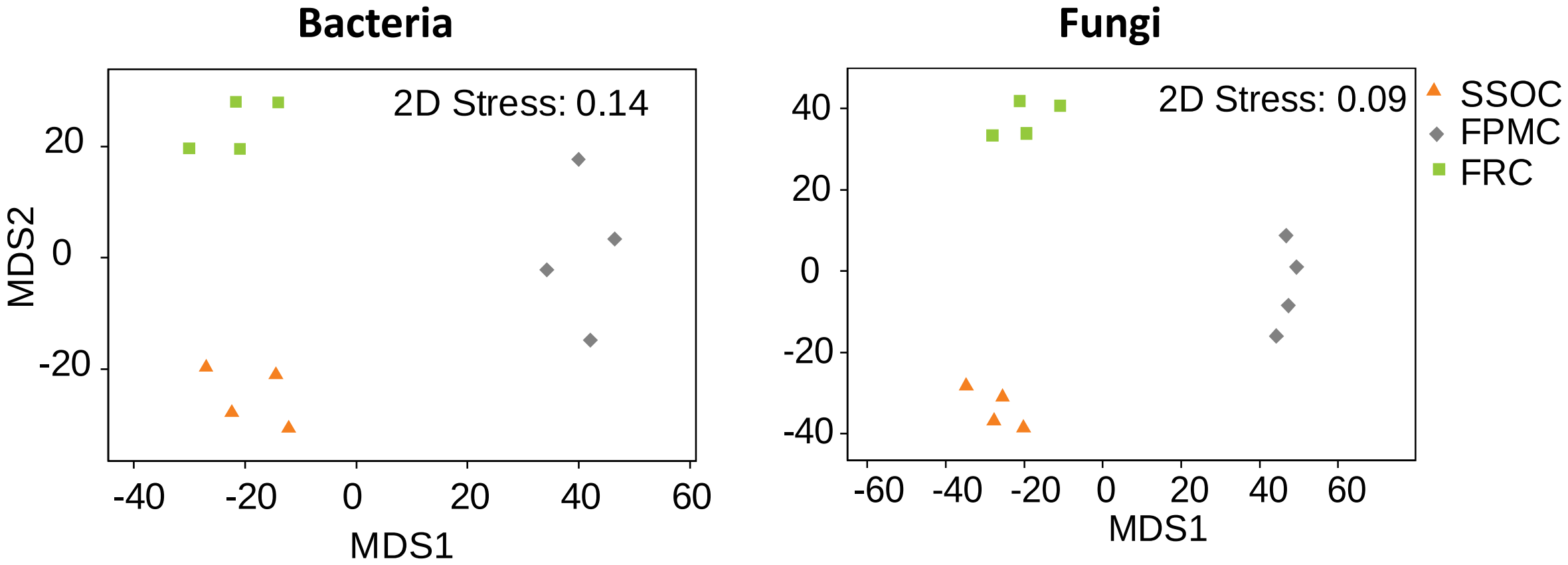




ANOVA ≤ 0.05

Results – Compost Microbiome

β-diversity using multidimensional scaling (MDS)

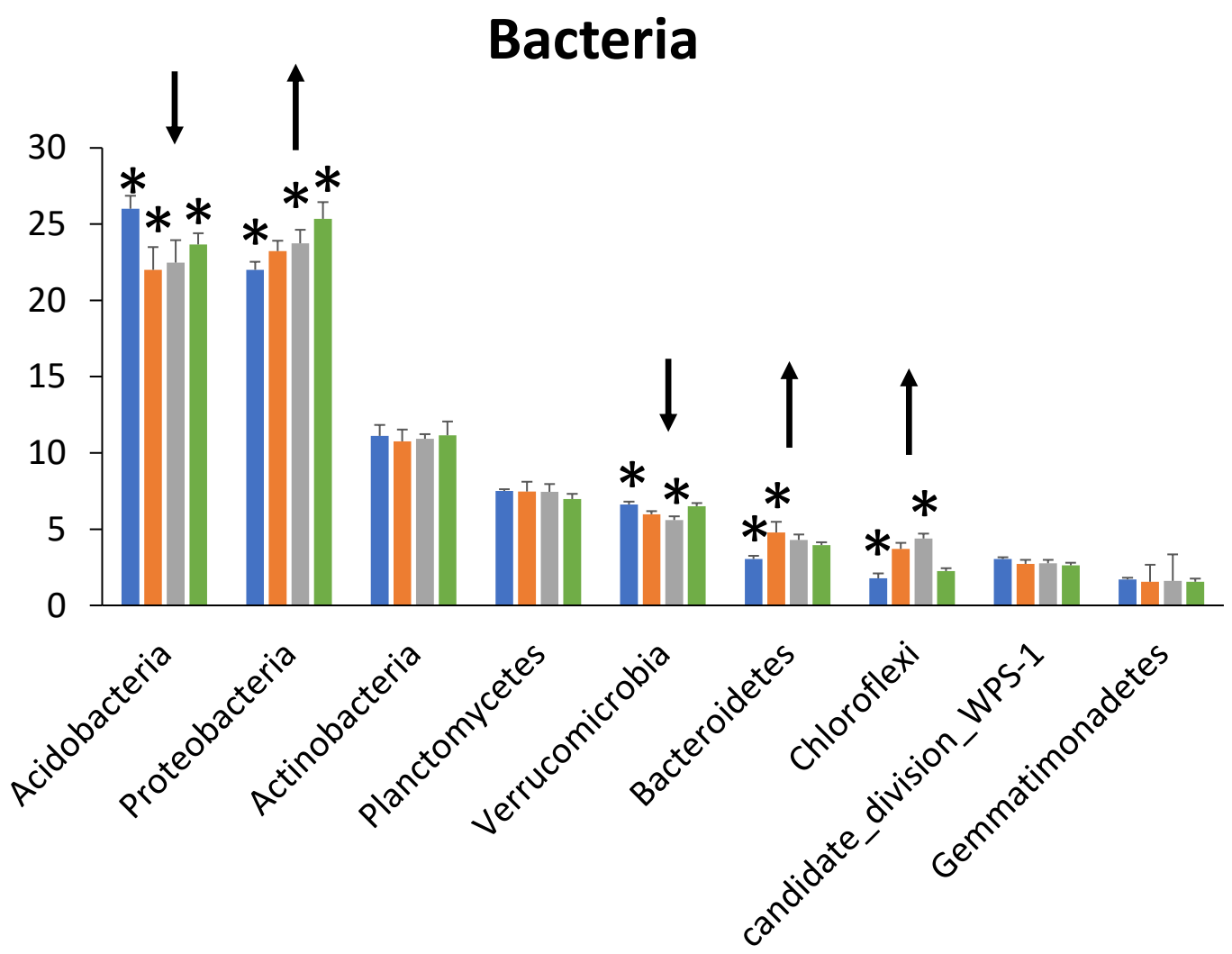


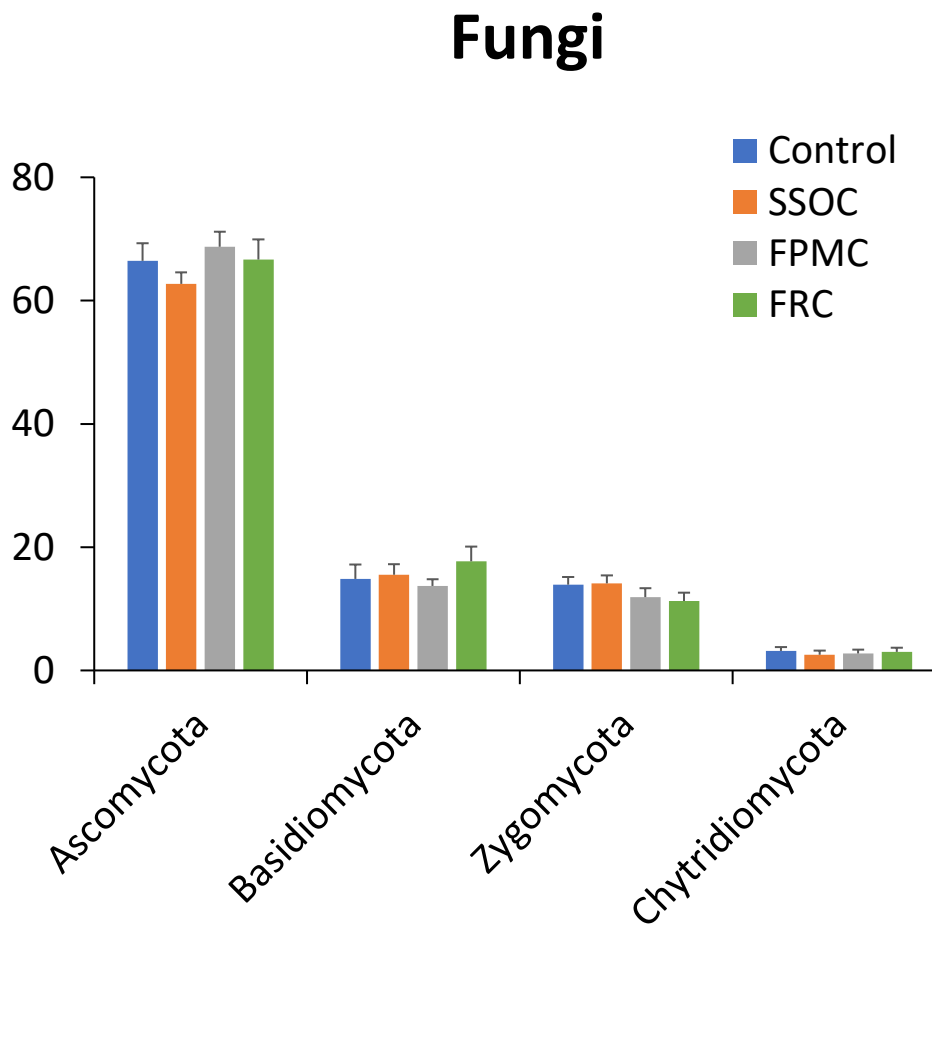
PERMANOVA p=0.004

PERMANOVA p=0.001

Results – Soil Microbiome

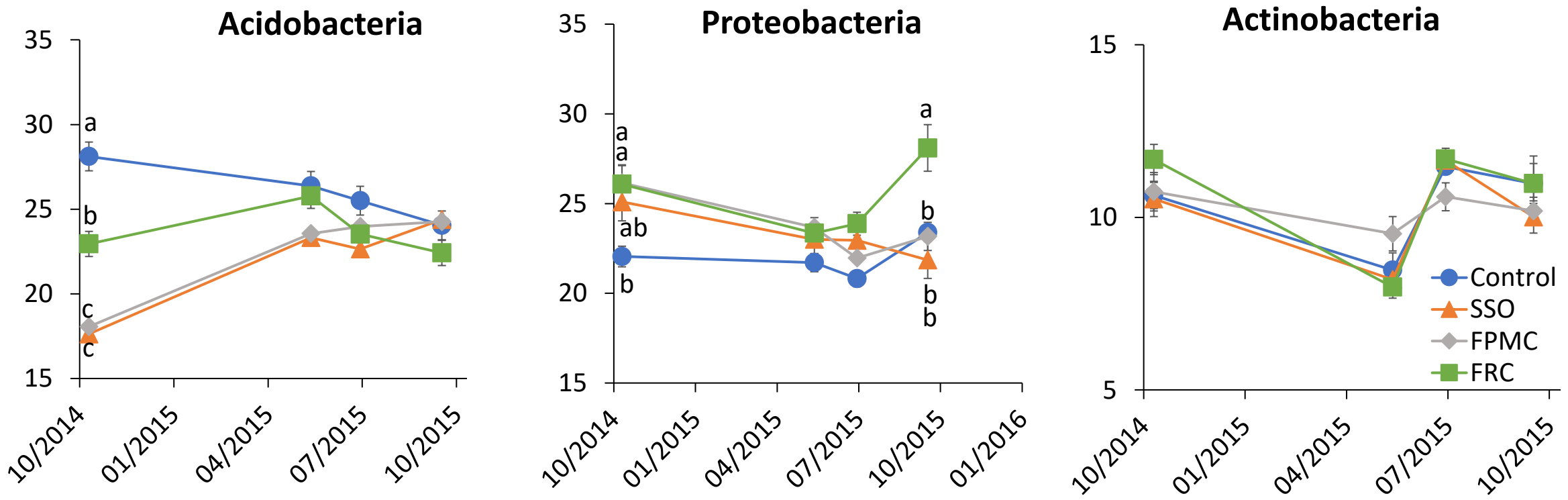
Relative abundance averaged over time (%)





Results - Soils

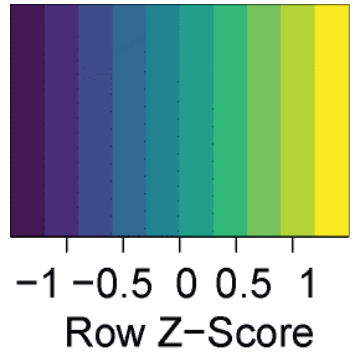
Relative abundance (%)



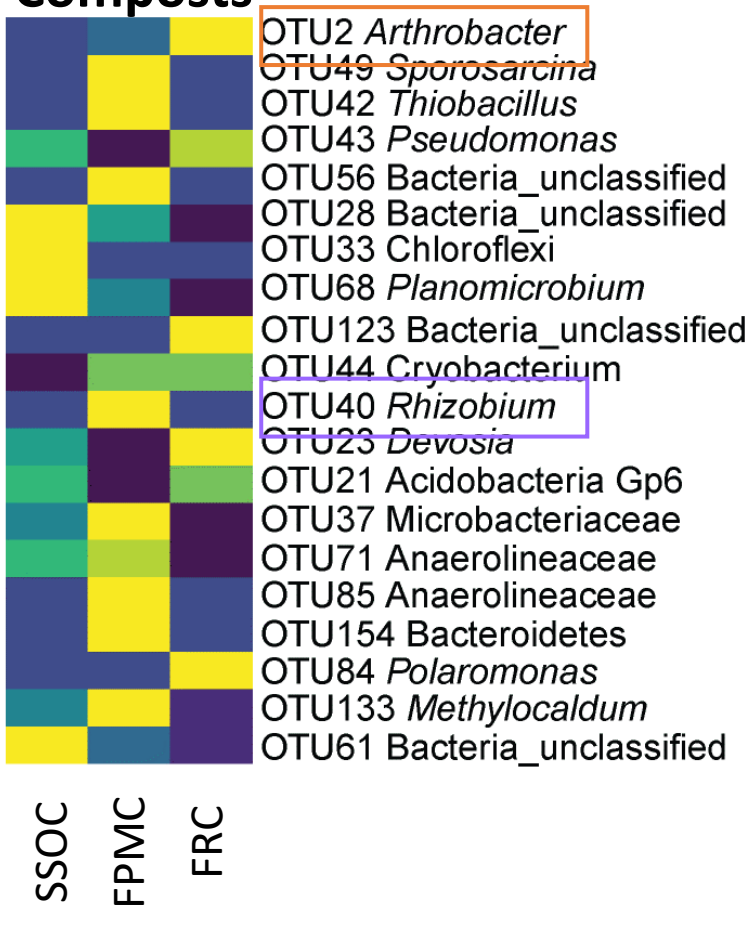
ANOVA ≤ 0.05

Results - Soils

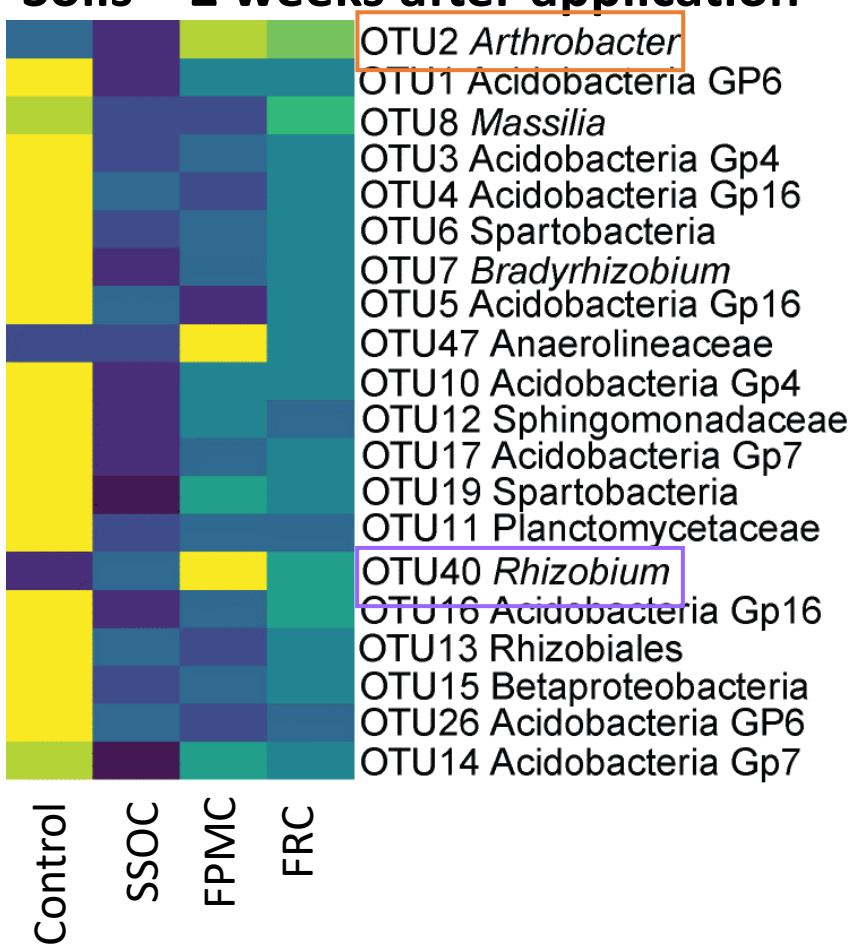
Relative abundance of bacterial species



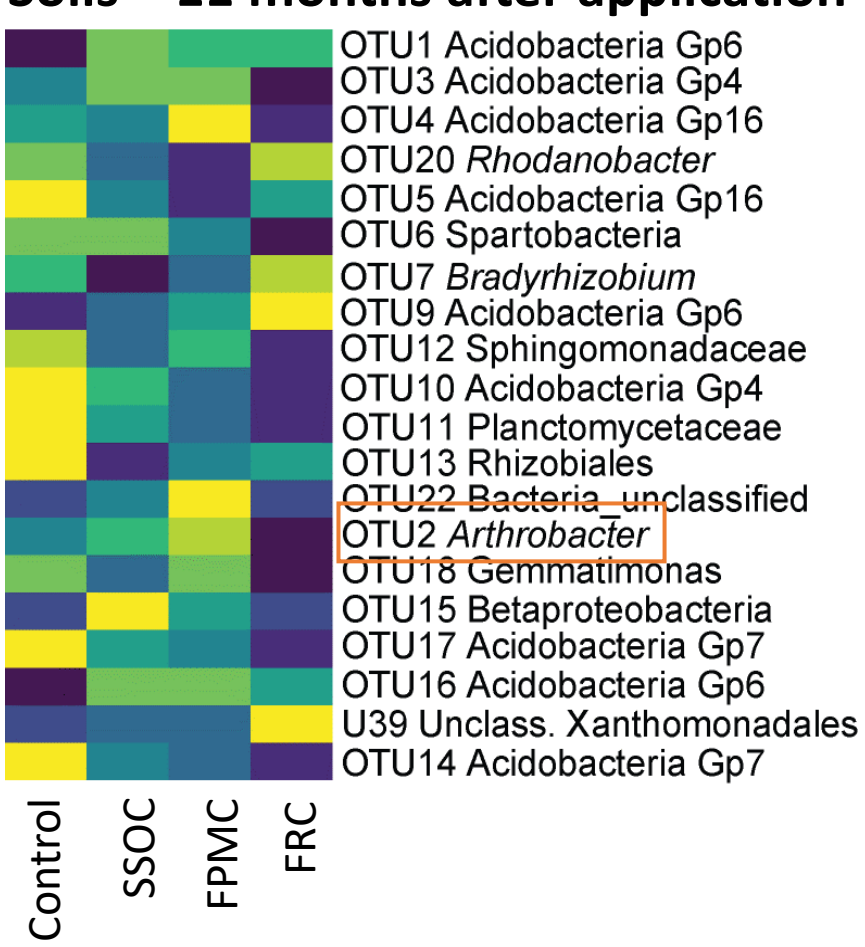
Composts



Soils – 2 weeks after application

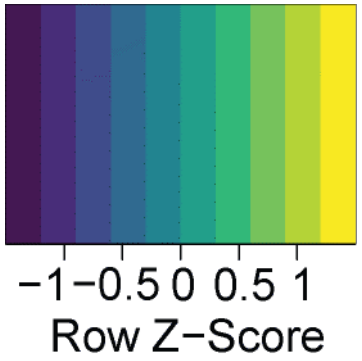


Soils – 11 months after application

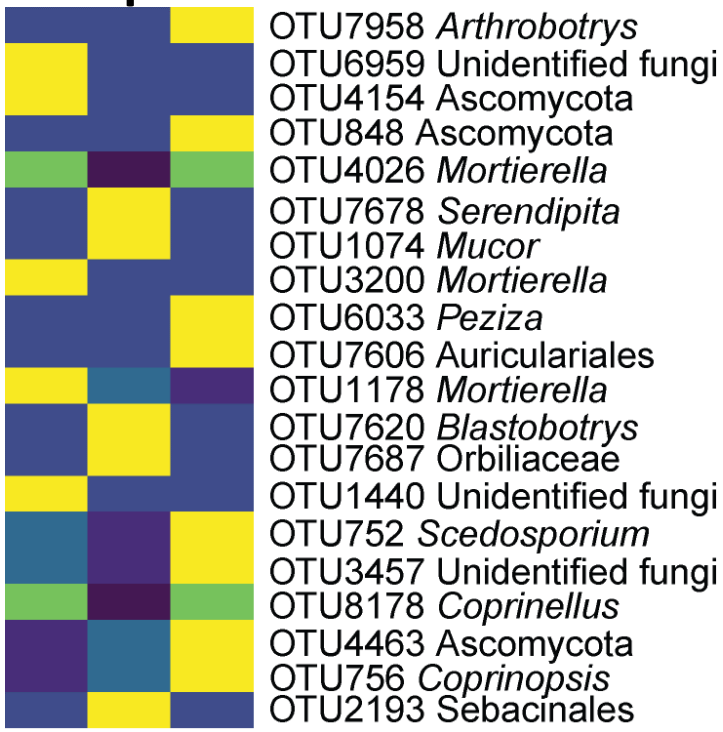


Results - Soils

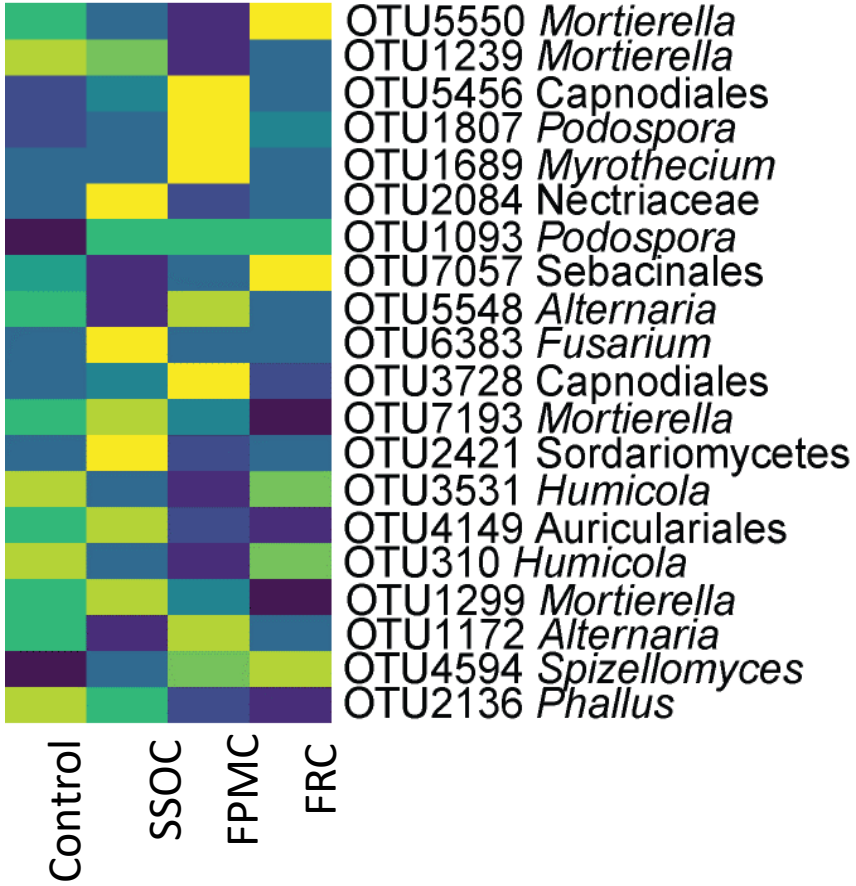
Relative abundance of fungal species



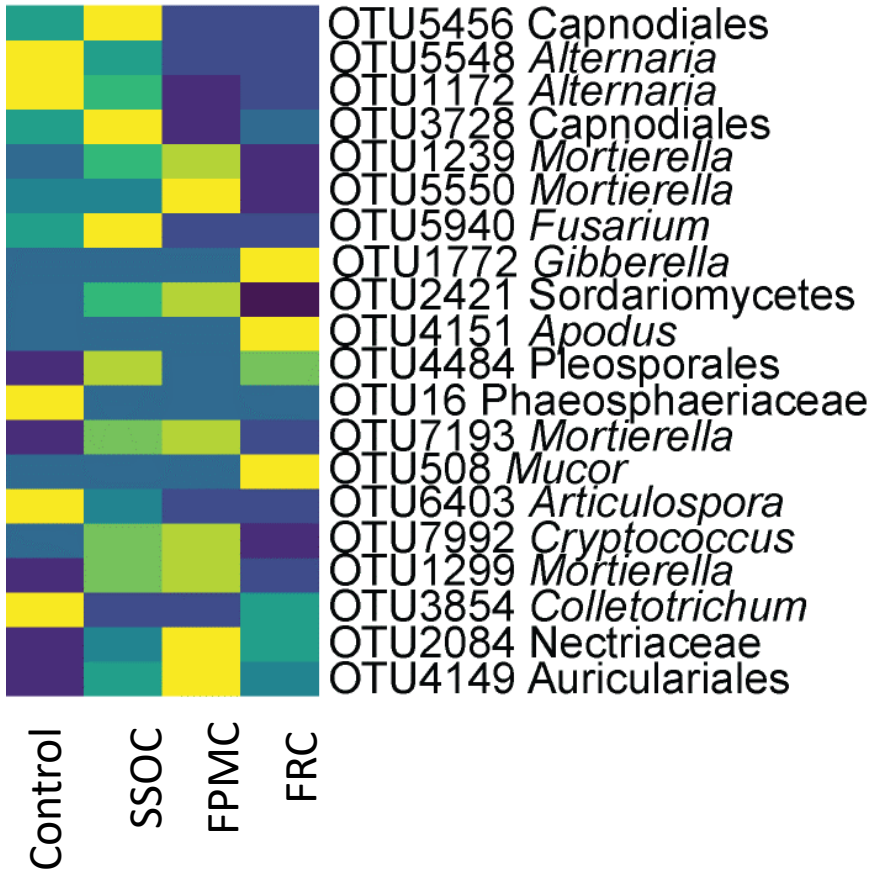
Composts



Soils – 2 weeks after application

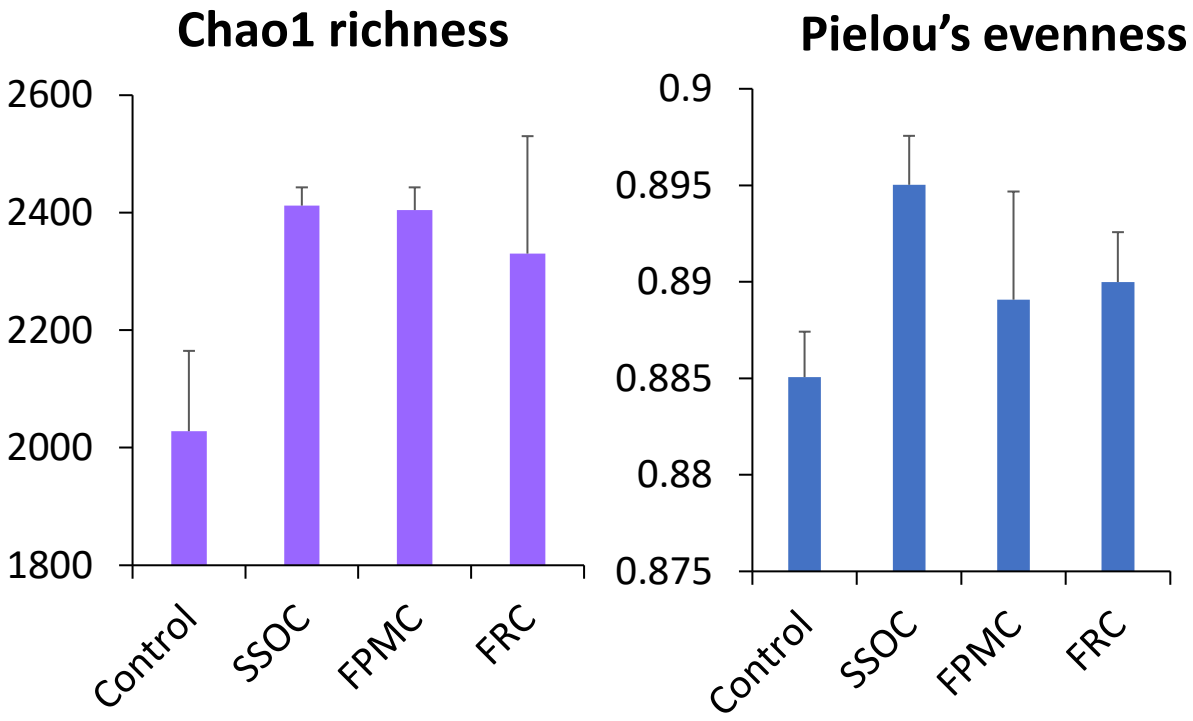


Soils – 11 months after application

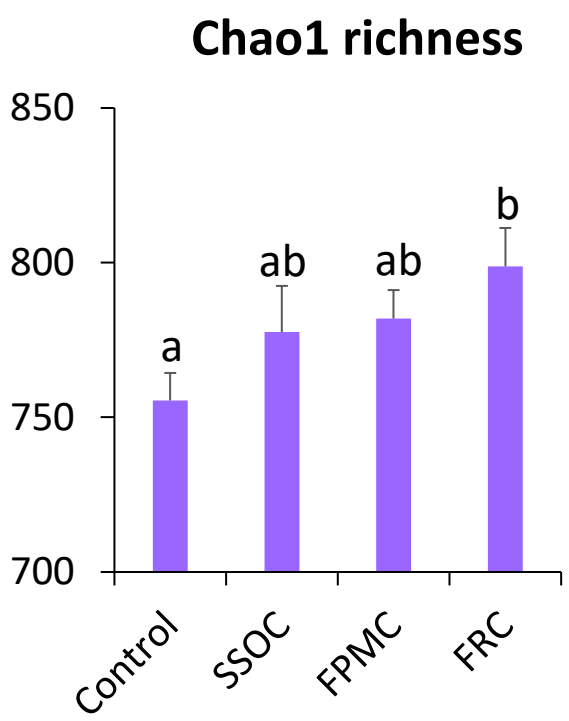


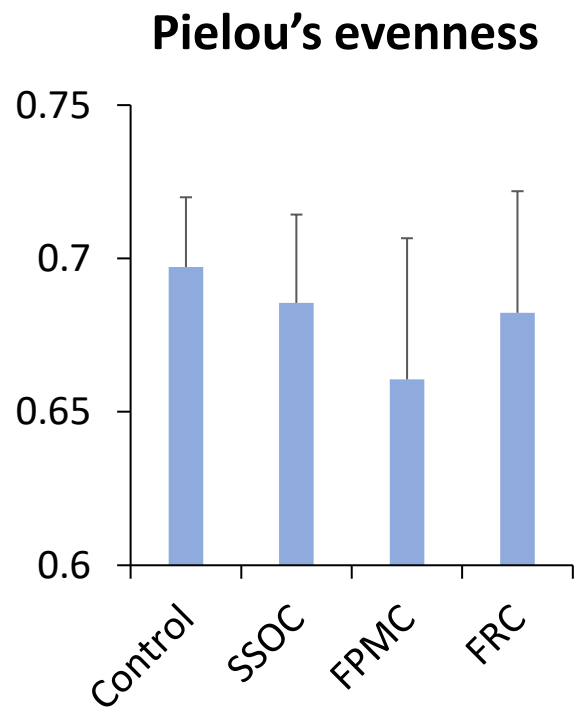
Results – biodiversity indices of soils

Bacteria



Fungi





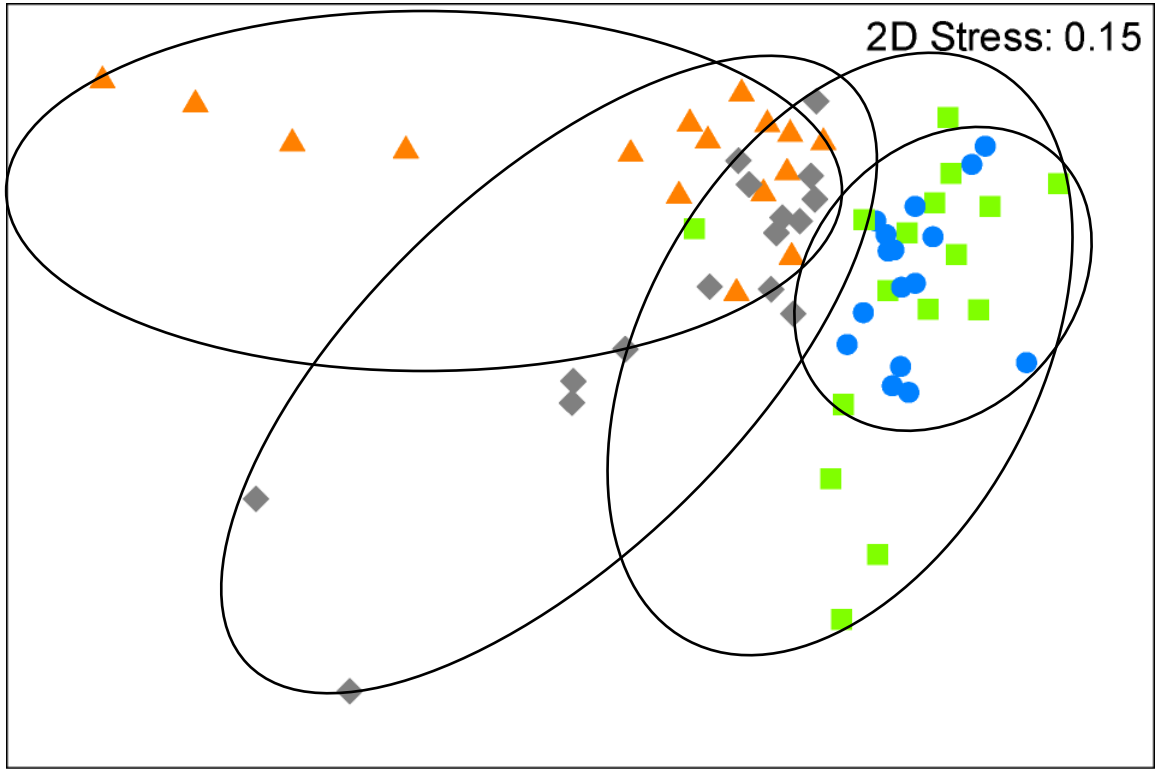
ANOVA ≤ 0.05

Results - Soils

β-diversity among treatments - nMDS

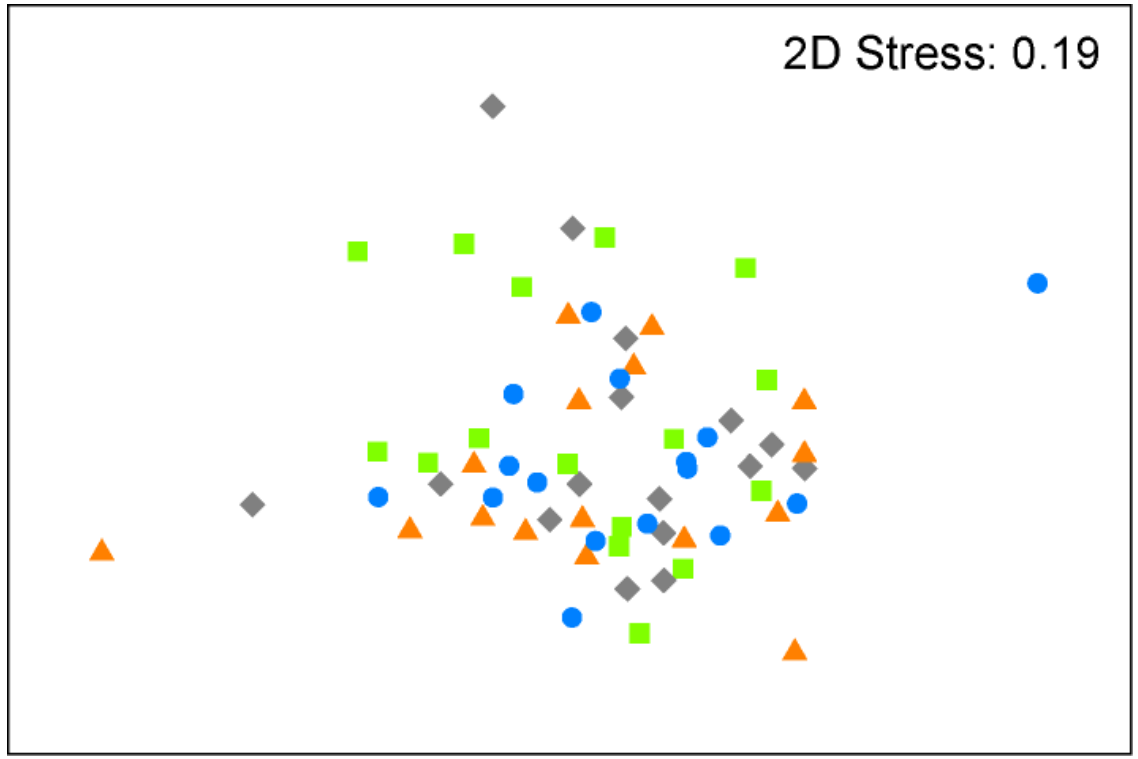
Control
SSOC
FPMC
FRC

Bacteria



PERMANOVA p=0.001

Fungi



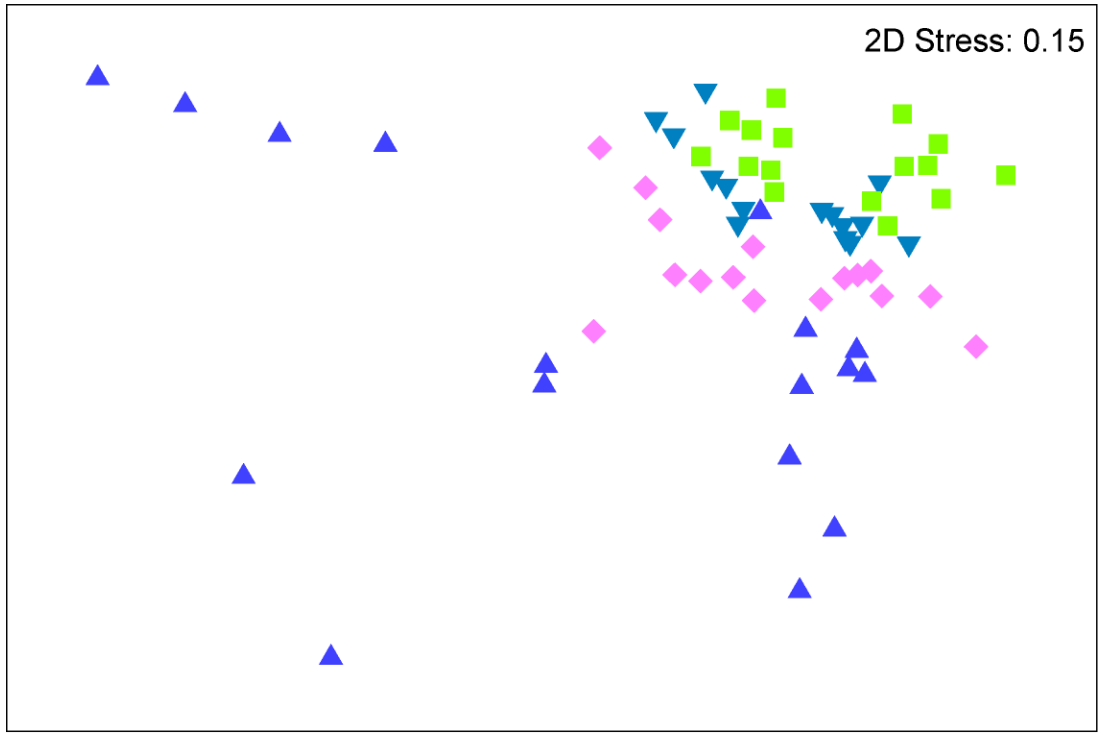
PERMANOVA p=0.001

Results

β-diversity over time - nMDS

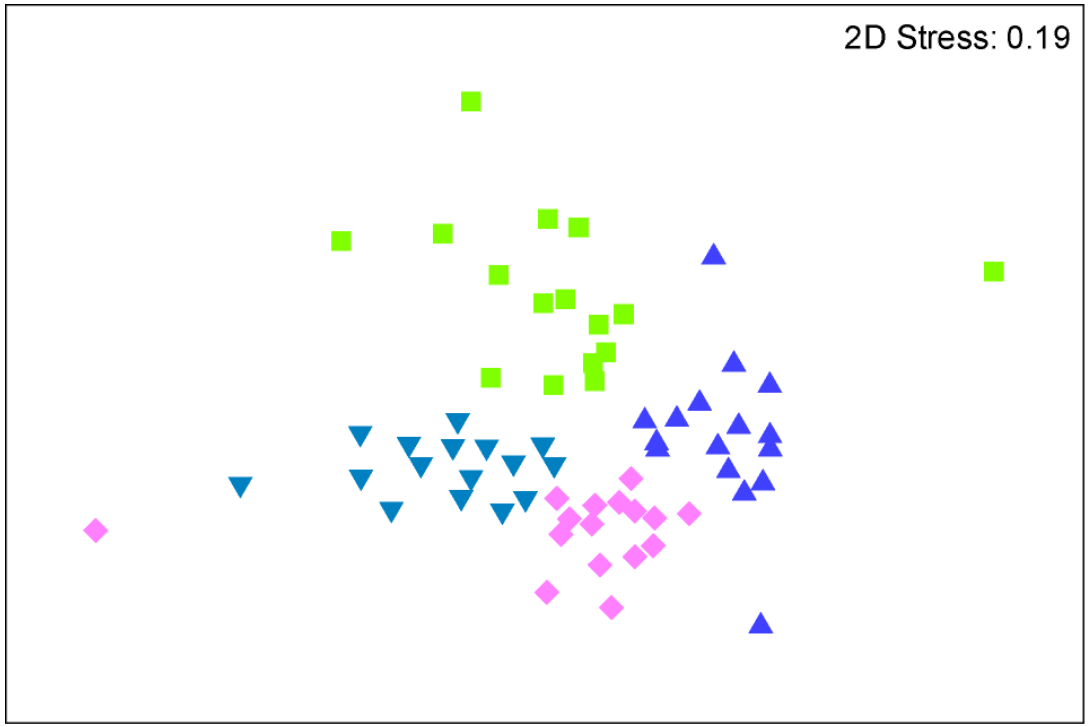
Oct. 2014
May 2015
Jul. 2015
Sept. 2015

Bacteria



PERMANOVA p=0.001

Fungi



PERMANOVA p=0.001

Conclusions

- Compost application changed soil structure, nutrient levels and affected different labile soil organic carbon fractions.
- Compost application resulted in a change in the diversity of bacterial and fungal communities that could be observed in the next growing season.
- Compost application did not result in an increase in potato yield.
- Compost is an excellent option to remediate poor quality soil but adoption by growers is difficult due to cost and the low potential for short-term return on investment.
- Soil quality is similar to infracture on a farm: it costs money but it is worth investing for the future.

Acknowledgments

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- Collaborators: Dr. Bernie Zebarth, Dr. David Burton (Dalhousie University)

- Sean Whitney, Sara Neupane, Carolyn Wilson, Ginette Decker, Karen Terry, Kyle MacKinley

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DALHOUSIE UNIVERSITY

Potatoes Pommes de terre NB

NEW BRUNSWICK / NOUVEAU-BRUNSWICK

CANADA

Composts

SSOC: organic curb-side waste composted in-vessel (Elmsdale Landscaping Inc.)

FPMC: windrow composting of poultry manure and wood shaving bedding, forestry wastes, paper mill residue, and wood ash (Brand RV045, Envirem Organics Inc.)

FRC: windrow composted predominantly from wood-waste feedstock including bark, paper mill residue, and wood-ash with approximately 5% broiler chicken manure (Black Earth, Envirem Organics Inc.).

MSC: marine with shells compost included marine waste (fin and shell fish), chicken compost, and ground aged wood fines in a windrow composting system (Atlantic Marine Compost, Cardwell Farms Compost Products).

MC: Poultry manure compost was windrow composted from chicken manure with ground aged wood fines (Bulk Poultry Compost, Cardwell Farms Compost Products).