

Summary of Research Progress

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Grant Project Title: Do Management Regimes of Organically and Conventionally Managed Golf Course Soils Influence Microbial Communities and Relative Abundance of Important Turf Pathogens?

Elisha Allan, M.S., Daniel Manter, Ph.D., Geunhwa Jung, Ph.D.

The first and second field collections for this research project were successfully completed in May and September of 2013. From the May 2013 collection all samples have been processed for nematode identification and counts, soil nutrient and texture analysis, and pyrosequencing analysis of bacteria and fungi. The September 2013 samples have been processed for soil nutrient and texture analyses. The nematode identification and counts of all of the greens samples have been completed and counts on the fairways and roughs are in progress. DNA extraction of these samples is in progress.

The preliminary results on the nematodes counts between the different management areas for the May 2013 collection were presented at the University of Massachusetts-Amherst Turf Field Day and the University of Massachusetts-Amherst Plant Biology Symposium. The preliminary results from the nematode counts from the May 2013 collection and the greens from the September 2013 collection, as well as the soil nutrient and texture data were presented at the American Society of Agronomy, Crop Science Society of America, and the Soil Science Society of America Annual Meetings, "Water, Food, Energy, & Innovation for a Sustainable World," Nov. 3-6, 2013, Tampa, FL as part of the C5 Turfgrass Oral Competition.

The results of our data suggest that the more intensely managed areas have higher plant pathogenic nematodes and fewer bacteriovores, one of free-living or potentially beneficial nematodes (Figs. 1 and 2). The pyrosequencing results showed higher diversity and abundance of bacteria on the conventional course and higher fungal abundance on the organic course and the organic and conventional roughs. This suggests that organic management may be more conducive to fungal growth. There were similar proportions of bacterial and fungal classes, with over 95% of the population of all holes being dominated by the alphaproteobacteria. However, the families comprising the alphaproteobacteria and the remaining 5% of the populations were significantly different between the courses and locations (Table 1).

Summary of Results

Nematode Results

- ANOVA results showed that percent plant pathogenic nematodes are significantly lower on the roughs and greens of the organic course than the conventional and hybrid courses. The most striking difference was that the organic greens had about 10% plant pathogenic nematodes versus about 90% plant pathogenic nematodes on conventional and hybrid greens (Figs. 1 and 2)
- ANOVA results showed percent bacteriovore nematodes was significantly higher on the roughs and greens of the organic course than the conventional and hybrid courses (Figs. 1 and 2)

- ANOVA results showed carnivorous nematodes are significantly higher on the organic course (all areas: greens, fairways, and roughs) than the conventional and hybrid courses (Figs. 1 and 2)
- Results of the partial least squares and bicluster analysis showed that (Fig. 3)
 - Fungivores were positively correlated with the Glomeromycetes and fungal abundance. The fungivores were negatively correlated with copper and the Hypocreales.
 - Plant pathogenic nematodes are positively correlated with lead, pH, phosphorous, zinc, Actinomycetes, boron, calcium, sulfur, potassium, Microascales, greater observed bacterial species, magnesium, and the Tremellomycetes. They were negatively correlated with manganese, Eurotiales, iron, soil density, greater observed fungal species, Halophage order *incertae sedis*, and the Sordiales.
 - Bacteriovores showed almost the exact opposite trends as the plant pathogenic nematode. They were positively correlated with zinc, Eurotiales, iron, soil density, Hypocreales, and the Chaetothyriales. They were negatively correlated with manganese, bacterial abundance, Sphingobacteriales, lead, pH, phosphorous, Actinomycetes, boron, calcium, sulfur, potassium, and the Microascales.

Pyrosequencing Results

- Bacteria (16S)
 - No significant differences in abundance between courses or locations
 - The conventional and hybrid course had more observed bacterial species than the organic course ($p < 0.0001$)
 - The conventional and hybrid course had significantly greater bacterial diversity than the organic course ($p = 0.003$)
 - The conventional and hybrid courses had significantly higher species evenness than the organic course ($p = 0.0002$)
- Fungi (18S)
 - The organic course had the highest species abundance (a), then conventional (ab), and hybrid (b) ($p = 0.0433$, different lowercase letters represent statistically significant differences by Student's T-test of least mean squared).
 - The rough had the greatest fungal abundance, then the fairway, and lastly the green ($p = 0.0024$).
 - The green had significantly fewer observed species than the rough and fairway ($p < 0.0001$) and lower fungal diversity ($p = 0.0308$)
 - There were no significant differences between species evenness.
- Bacteria abundance compared to fungal abundance
 - 16S/18S was significantly different between courses ($p = 0.0155$) and locations ($p = 0.0004$), different lowercase letters represent statistically significant differences by Student's T-test of least mean squared.
 - Hybrid/conventional (a), Organic (b)
 - Green/fairway (a), Rough (b)

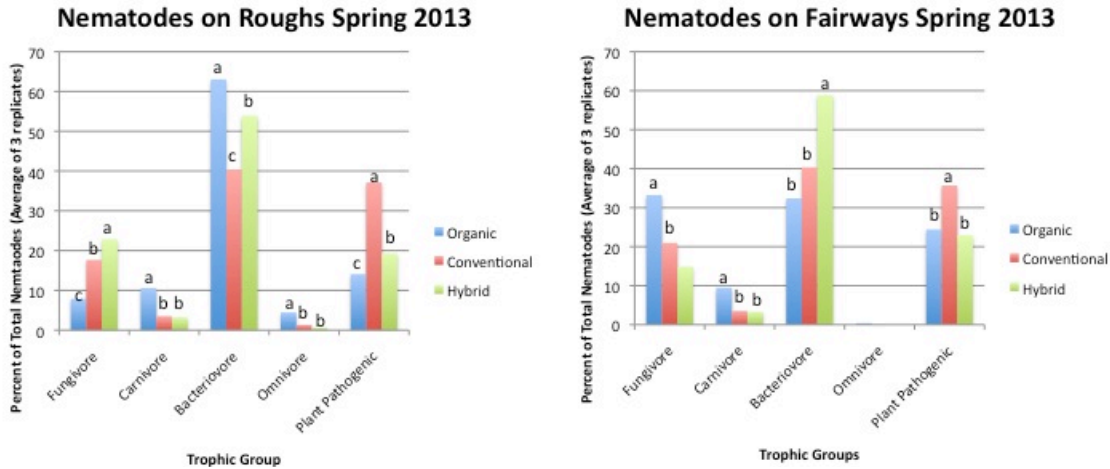


Figure 1. Percent frequency of nematodes in each trophic group on the roughs and fairways sampled in Spring 2013. Different lowercase letters represent statistically significant differences by Student's T-test of least mean squared.

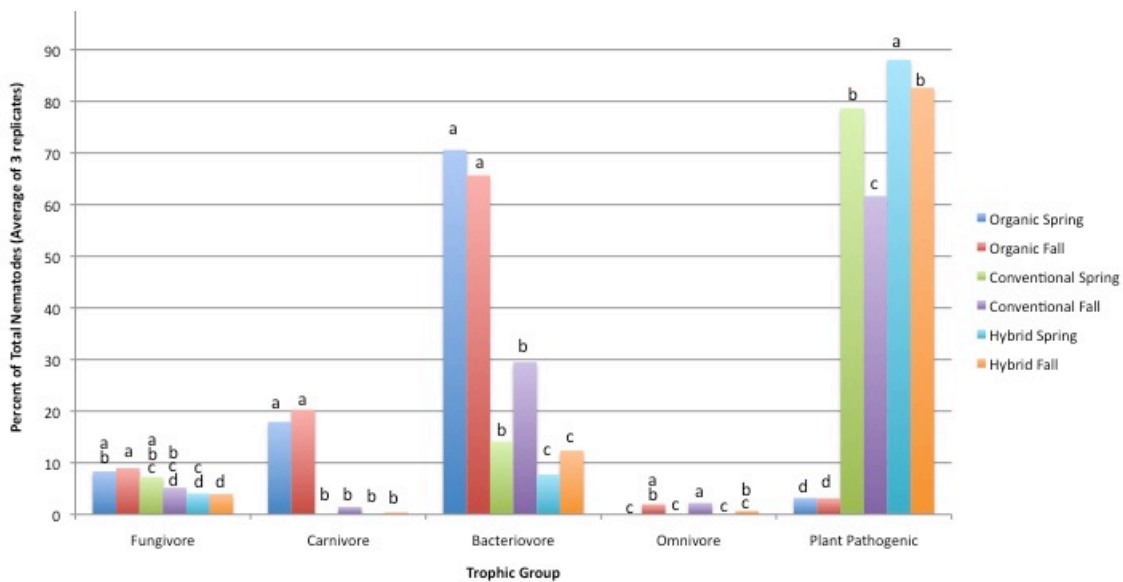


Figure 2. Percent frequency of nematodes in each trophic group on the greens sampled in Spring and Fall 2013. Different lowercase letters represent statistically significant differences by Student's T-test of least mean squared.

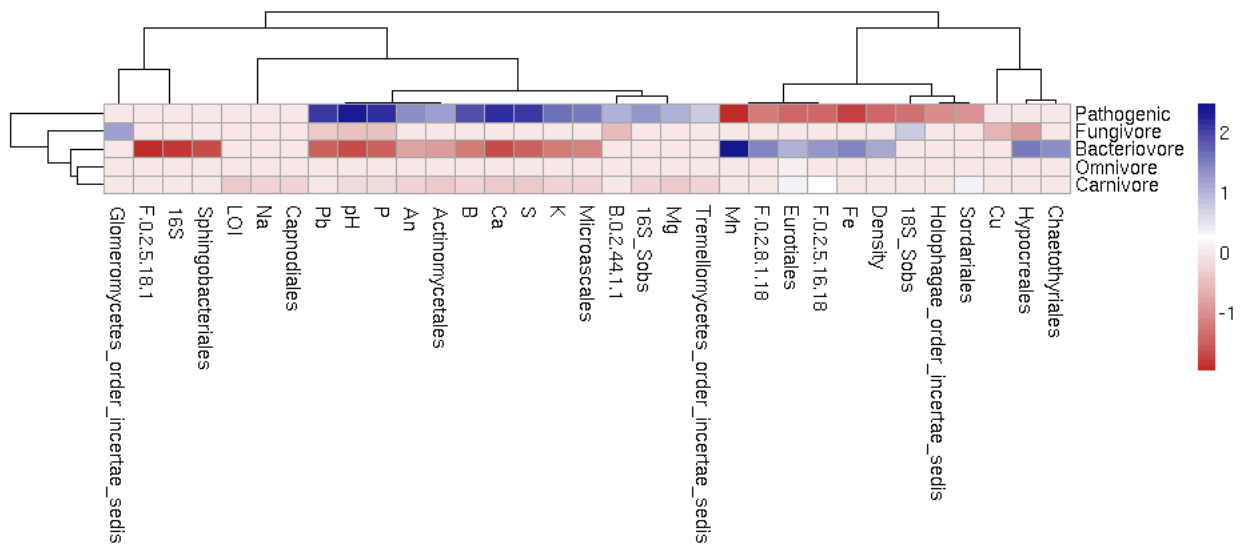


Figure 3. Bicluster analysis of the results of the partial-least squares analysis of the soil factors, bacterial, and fungi that most significantly influencing nematode population proportions. Blue indicates a significant positive correlation and red indicates a significant negative correlation.

Table 1. Classes of bacteria and fungi that are significantly different among courses or locations as determined by ANOVA analysis. Different letters signify significant differences as determined by the Student's T-test.

Class	p value	T test Results	p value	T test Results
Acidobacter	0.0041	Organic A Hybrid B Conventional B		
Actinobacter	0.0002	Conventional A Hybrid B Organic C	0.0002	Fairway A Rough B Putting Green C
Anaerolineae	0.0016	Hybrid A Conventional B Organic B		
Bacteria class <i>incertae sedis</i>	0.0234	Hybrid A Conventional AB Organic B		
Betaproteobacteria	0.0017	Conventional A Hybrid B Organic B		
Caldilinea	0.0267	Conventional A Hybrid A Organic B	0.0471	Putting Green A Rough AB Fairway B
Chloroflexi	0.0068	Conventional A Hybrid A Organic B	0.0357	Putting Green A Rough AB Fairway B
Chytridiomycetes class <i>incertae sedis</i>	0.0256	Conventional A Hybrid A Organic B	0.0019	Putting Green A Fairway A Rough B
Deltaproteobacteria	0.0157	Conventional A Hybrid A Organic B		
Entorrhizomycetes	0.0498	Organic A Hybrid B Conventional B		
Eukaryota class <i>incertae sedis</i>			0.002	Putting Green A Fairway A Rough B
Eurotiomycetes			0.0285	Rough A Fairway B Putting Green B
Gammaproteobacteria	0.0011	Organic A Conventional A Hybrid B	0.0256	Rough A Fairway AB Putting Green B
Gemmatimonadetes	0.0065	Conventional A Hybrid A Organic B	0.0098	Putting Green A Rough B Fairway B
Glomeromycetes			<0.0001	Putting Green A Fairway B Rough C
Holophage	0.0017	Conventional A Hybrid B Organic B	0.0185	Fairway A Putting Green A Rough B
Ktenobacteria			0.0405	Fairway A Rough AB Putting Green B
Leotiomycetes	0.0235	Organic A Hybrid B Conventional B		
Liliopsida	0.0048	Hybrid A Conventional B Organic B		

Lineage IIA	<0.0001	Organic A Hybrid B Conventional B		
Nitrospira	0.0103	Conventional A Hybrid A Organic B	0.0147	Putting Green A Rough B Fairway B
OPI class <i>incertae sedis</i>	0.038	Hybrid A Conventional AB Organic B		
OPII class <i>incertae sedis</i>	0.0006	Organic A Hybrid B Conventional C		
Orbiliomycetes			0.002	Putting Green A Rough B Fairway B
Pezizomycetes			0.0128	Putting Green A Rough B Fairway B
Saccharomycetes	0.0109	Organic A Hybrid B Conventional B		
TM7 class <i>incertae sedis</i>	0.0131	Conventional A Hybrid A Organic B		
Verrucomicrobia class <i>incertae sedis</i>	0.0379	Hybrid A Organic AB Conventional B		