How does Soil Respond to Wild-Type Endophyte Infection?

INVESTIGATORS

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HYPHOTHESIS

Greater tall fescue growth and/or reduced soil microbial activity may be causing organic C to accumulate to a greater extent in soil under tall fescue with wild-type infection.

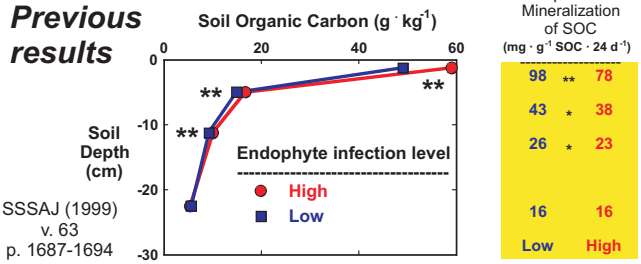
OBJECTIVE

To ascertain possible mechanisms that control soil organic C accumulation with endophyte infection, we conducted short-term controlled studies and sampled a long-term field study.

RATIONALE

- Toxic effects of *Neotyphodium*-infected tall fescue on grazing animals have been well documented.
- Ecologically, the presence of *N. coenophialum* may be important for improving tall fescue persistence in marginal ecoregions.
- Pastures with high occurrence of wild-type endophyte-infected tall fescue have also been found with greater soil organic C and N concentration.
- The magnitude of change in soil organic C (1.8 Mg/ha) that was observed under high- versus low-endophyte infection suggests that if this difference were realized on the 14 Mha of tall fescue in the USA, there would be the potential to sequester 25 Tg of soil organic C due to endophyte infection of tall fescue alone. This change would be in addition to an estimate of 112 Tg of soil organic C that would be sequestered due to planting of tall fescue compared with conventional-tillage cropping.

Previous results



SSSAJ (1999) v. 63 p. 1687-1694

APPROACHES

Long-term field study

- 12 experimental units (0.7-ha paddocks) 2 plant trts ('Kentucky -31' tall fescue with low (<7%) and high (80%) endophyte infection) x 2 fertilization levels (134 and 336 kg N/ha/yr) x 3 replications
- soil sampled at 0-3, 3-6, 6-12, and 12-20 cm depths
- soil organic C and N determined with dry combustion
- water infiltration with single ring (30-cm diam) during 60 min

Short-term growth study

- 48 experimental units (2.5 kg soil in 15-cm-diam pots) 2 plant trts (zero and high endophyte infection) x 2 soils (clay and sand) x 4 harvest dates (8, 20, 36, and 60 wks) x 3 replications
- grown under outdoor conditions with supplemental water
- Measurements of plant growth, soil organic C-N, particulate C-N, soil microbial biomass C, mineralizable C-N, aggregation, and microbial diversity (BIOLOG, FISH)

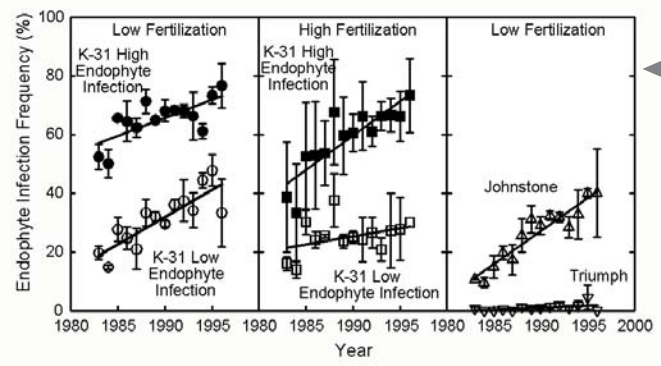
Short-term decomposition study

- 96 experimental units (100 g soil + 5 g fresh leaf addition) 2 leaf trts (zero and high endophyte infection) x 2 soils (taken from under long-term zero and high endophyte infection) x 8 harvest dates (0, 1, 2, 4, 8, 16, 32 (2x) days) x 3 replications
- Sealed jars at 25 °C and 50% water-filled pore space
- Measurements of C and N mineralization (CO_2, NH_4, NO_3), soil microbial biomass C (chloroform fumigation-incubation), alkaloids remaining in leaf, water extract, and soil (ELISA)

RESULTS

Long-term field study

Carbon and nitrogen contents of small macroaggregates (0.25-1 mm) were the only soil properties that were related (r = 0.70, *p* = 0.001) to endophyte infection frequency (range of 1 to 79%) across all treatments. Soil C and N pools can be modified by endophyte infection, but these results narrowed this phenomenon to (1) conditions of higher fertility and (2) predominantly in small macroaggregates.



Soil C and N pools at a depth of 0 to 12 cm as affected by fertilization and endophyte infection level at the end of 20 years of management.

Fert	Endo	SOC	POC	CMIN	LMa	SMa	Micro
		kg C m^{-2}					
Low	E-	2.88	1.20	0.128	2.05	0.98	0.18
Low	E+	2.97	1.16	0.133	2.22	1.00	0.17
High	E-	2.98	1.31	0.130	2.25	0.94	0.17
High	E+	3.28	1.32	0.124	2.40	1.10	0.14
Analysis of variance (Pr > F)							
Endophyte		0.10	0.78	0.93	0.54	0.01	0.47
Fertilization		0.08	0.05	0.60	0.46	0.28	0.61
Endo x Fert		0.36	0.69	0.45	0.97	0.04	0.31

SOC is soil organic C, POC is particulate organic C, CMIN is potential C mineralization during 24 days of incubation, LMa is large macroaggregates (>1 mm), SMa is small macroaggregates (0.25-1 mm), and Micro is microaggregates (<0.25 mm).

Short-term growth study

During 60 weeks of growth, dry matter production was greater with wild-type endophyte infection than without. However, total and particulate organic C pools were negatively affected by the presence of the endophyte.

Soil responses to endophyte infection tended to be stronger in a sandy loam than in a clay loam (data not shown), suggesting possible implications of soil texture on response.

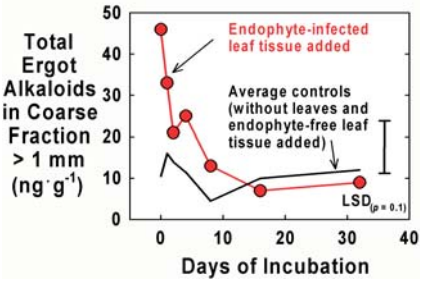
The short-term growth study revealed changes in soil C pools that were opposite to field studies, suggesting that long-term expression of endophyte effects might possibly be different than short-term effects.

Plant and soil properties from 'Jesup' tall fescue averaged across 4 sampling dates during 60 weeks of growth without (E-) and with (E+) wild-type endophyte infection.

Property	E-	Prob > F	E+
Dry matter production (g/pot)	31	0.10	33
Soil organic C (g/kg)	3.8	0.07	3.6
Particulate organic C (g/kg)	1.1	0.06	1.0
Soil microbial biomass C (mg/kg)	235	0.43	226
Mineralizable C (mg/kg/24 d)	227	0.51	218
Macroaggregate C (g/kg)	1.6	0.37	1.7

Short-term decomposition study

Ergot alkaloids were quickly released from E+ leaves during decomposition, but there was a significant background level in soil under 10-year-old E+ tall fescue, suggesting environmental persistence and possible impacts on soil.



Addition of endophyte-infected (E+) leaves to soil during a 32-day incubation restricted C dynamics, but stimulated N dynamics compared with endophyte-free (E-) leaves.

Property (mg C or N / kg soil)	Leaf addition None	E-	Pr > F	E+
Potential C mineralization	49	688	0.003	660
Soil microbial biomass C	291	583	0.08	487
Net N mineralization	16	59	0.08	70
Soil microbial biomass N	5	19	0.02	56

Ergot alkaloid concentration (ug/100 g vessel) in soil fractions as affected by 10 years of pasture management.

Fraction	E-	Pr > F	E+
Soil sediment	1.2	0.01	2.8
Coarse fraction (>1 mm)	0.22	<0.001	0.58
Water extract	0.022	0.008	0.027

SUMMARY

- Increased soil organic C with wild-type endophyte infection (E+) of tall fescue was verified in a 20-year-old field study, but not in a 60-week growth study.
- Addition of E+ leaves reduced soil microbial biomass C and its activity, but enhanced biomass N and its activity.
- Ergot alkaloids were detected in soil under 10-year-old tall fescue pastures, despite rapid decomposition in soil.

CONCLUSION

Whether ergot alkaloids were directly or indirectly responsible for altered soil organic matter dynamics was not determined. However, these results verify that soil biochemical properties are significantly altered by endophyte infection of tall fescue.