Soil Responses to Tall Fescue Endophyte Infection

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RATIONALE

Pastureland accounts for 51 Mha of the 212 Mha of privately held grazing land in the USA.

From Kimble JM, Follett RF, Lal R, 2001. Introduction: The characteristics and extent of U.S. grazing lands. P. 3-16. In: Follett RF, Kimble JM, Lal R (Editors): The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect. Lewis Pub., Boca Raton FL

Tall fescue is the most important cool-season perennial forage for many beef-cattle producers in the humid region of USA.

A fungal endophyte, Neotyphodium, infects the majority of tall fescue stands with a mutualistic association. Tall fescue provides energy, nutrients, shelter, and propagation through the seed, while *Neotyphodium* provides biochemical deterrents to overgrazing and insect pressures.

Ergot alkaloids produced by the endophyte have major negative impacts on cattle performance.

OBJECTIVE

Quantify soil responses to endophyte infection to be able to eventually elucidate the mechanisms of how endophyte infection might alter soil organic matter dynamics.

APROACHES

Long-term field study

- 12 experimental units (0.7-ha grazed 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

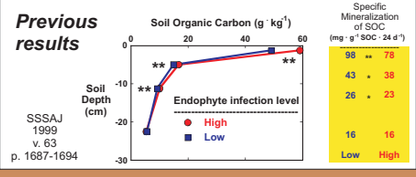
Short-term growth study

- 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)

Previous results



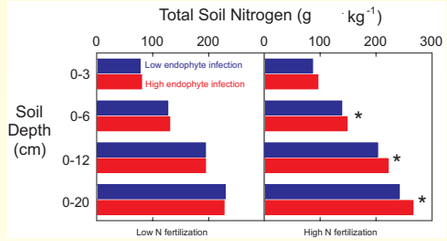
SSSAJ 1999 v. 63 p. 1687-1694

RESULTS

Long-term field study

Soil organic C and total soil N in 20-year-old 'Kentucky-31' tall fescue pastures were greater with high endophyte infection (80%) than with low endophyte infection (40%), but only with high N fertilization (34 g m^{-2} yr^{-1}) and not with low N fertilization (13 g m^{-2} yr^{-1}). The difference in total soil C and N between low and high endophyte infection at the end of 20 years was 325 and 24.4 g m^{-2}, suggesting a sequestration rate of 16.2 g m^{-2} yr^{-1} of soil organic C and 1.22 g m^{-2} yr^{-1} of total soil N.

These results partly confirm earlier results from the same pastures at the end of 15 years of management, where sequestration rates due to the presence of the endophyte were 18.2 g m^{-2} yr^{-1} for soil organic C and 1.25 g m^{-2} yr^{-1} for total soil N to a depth of 30 cm (Franzluebbers et al., 1999; SSSAJ 63:1687-1694).



Rate of water infiltration (cm h^{-1}) under tall fescue pastures with (+) and without (–) endophyte on 22 September 1997:

	–	Pr > F	+
Mean (n = 8)	12.8	0.02	20.8
Standard deviation	3.5		7.1

- Analysis of soil from the ***long-term field study*** indicates potential for greater soil organic C and N sequestration and water infiltration with endophyte infection.

Short-term growth study

Plant and soil properties from 'Jesup' tall fescue with (+) and without (–) 'wild-type' endophyte transplanted into clay loam and sandy loam soils in April 2002.

Property / weeks	Clay loam –	Clay loam +		Sandy loam –	Sandy loam +	
Cumulative dry matter (root+above-ground) (kg · m⁻²)						
8	0.27	0.24	ns	0.35	0.34	ns
20	2.68	2.73	ns	3.57	2.85	ns
36	4.72	4.85	ns	5.54	5.89	ns
60	7.62	8.80	ns	8.96	11.16	*
Total soil organic C (g · kg⁻¹)						
8	1.0	0.8	ns	3.9	3.9	ns
20	1.7	1.6	ns	4.3	4.6	*
36	3.6	2.8	ns	5.8	5.5	ns
60	3.7	3.4	ns	6.1	6.0	ns
Particulate organic C (g · kg⁻¹)						
8	0.2	0.2	ns	0.7	1.0	*
20	0.5	0.5	ns	1.2	1.1	*
36	1.0	1.0	ns	1.5	1.6	ns
60	1.5	1.3	*	2.1	1.5	*
Soil microbial biomass C (mg · kg⁻¹)						
8	114	142	ns	209	207	ns
20	225	207	ns	261	232	ns
36	248	191	ns	283	290	ns
60	202	201	ns	338	335	ns
C in water-stable aggregates >1 mm (g · kg⁻¹ aggregate)						
8	2.5	2.0	ns	4.8	6.0	ns
20	9.8	8.0	ns	16.3	9.5	ns
36	22.7	27.0	ns	19.2	28.4	ns
60	26.1	25.8	ns	25.4	30.0	ns
C in water-stable aggregates 0.25-1 mm (g · kg⁻¹ aggregate)						
8	0.6	0.7	ns	2.8	3.3	ns
20	0.9	1.0	ns	3.6	3.5	ns
36	2.4	2.5	ns	5.0	3.9	ns
60	2.6	2.1	*	4.4	4.4	ns
C in water-stable aggregates 0.05-0.25 mm (g · kg⁻¹ aggregate)						
8	1.1	1.0	ns	5.3	5.0	ns
20	1.3	1.3	ns	5.2	5.7	ns
36	2.0	2.1	ns	5.9	6.6	ns
60	3.1	2.7	ns	6.2	6.8	ns

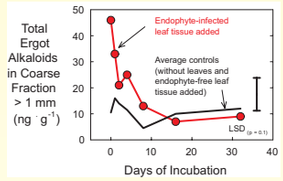
* is significant at $p \leq 0.1$, ns is not significant.

- A ***short-term growth study*** revealed few consistently significant changes in soil organic C pools, suggesting that endophyte effects might require >1 year to be expressed. There was some indication of greater productivity potential with endophyte infection than without.

Short-term decomposition study

Addition of 'K-31' tall fescue leaf tissue with (+) and without (–) endophyte resulted in the following **increases in soil C pools**:

	–	Pr > F	+
Soil microbial biomass C (mg · kg⁻¹ soil)	293	0.12	196
Potential C mineralization (mg · kg⁻¹ soil · 32 d⁻¹)	1256	0.06	1227



Ergot alkaloids (ng g^{-1}) in coarse and fine fractions of soil averaged across extractions at 0, 1, 2, 4, 8, 16, and 32 days of incubation following addition of tall fescue leaf tissue:

	Leaf tissue added None	E-	E+
Coarse fraction (leaf + sand >1 mm)		$LSD_{\|p=0.1\|}$ = 10	
E- soil	9	14	20
E+ soil	33	40	44
Fine fraction (soil <1 mm)		$LSD_{\|p=0.1\|}$ = 18	
E- soil	8	16	10
E+ soil	22	21	40

- Addition of endophyte-infected leaf tissue during a 32-day incubation tended to limit soil microbial biomass and activity compared with addition of endophyte-free leaf tissue.
- Ergot alkaloids appeared to be quickly released from tall fescue leaf tissue during decomposition, but there was a significant background level in soil under 10-year-old endophyte-infected tall fescue that suggested persistence and possible impacts on soil.

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