

Chemical Quality of Litter as a Driver of Detrital Community Assemblage in Mineral Soil

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Abstract

Quality of resources may be the strongest driver of consumer populations in soil. Understanding the short term effects of plant litter quality on soil detrital food webs is of special importance in integrated agricultural systems where organic soil amendments are seasonally applied to enhance fertility. In systems in which plant litter is not incorporated into the mineral soil it is crucial to distinguish between the litter communities and the mineral soil communities as they play different functional roles. This study investigated the short term effect of the chemical composition of one-time surface-applied amendments on the microbial, micro- and mesofauna communities in the mineral soil. We used five different substrates and a mixture and attempted to determine (a) the effect of substrate type on litter and soil communities and (b) the biochemical parameters, soil or community variables that most influenced the abundances of community members during the first six months of decomposition. Substrate type did not affect total soil PLFAs or microbial biomass, but it significantly affected the structure of the microbial community. Litter N and P and soil mineral N were the main drivers of the response early in the process and %C, %Lignin and Lignin/N played greater roles at later stages. Bacterial groups responded to more variables and their responses lasted longer than those of fungi. Microbial-feeding nematodes showed significant relationships with soil mineral N but these disappeared after three weeks.



Introduction

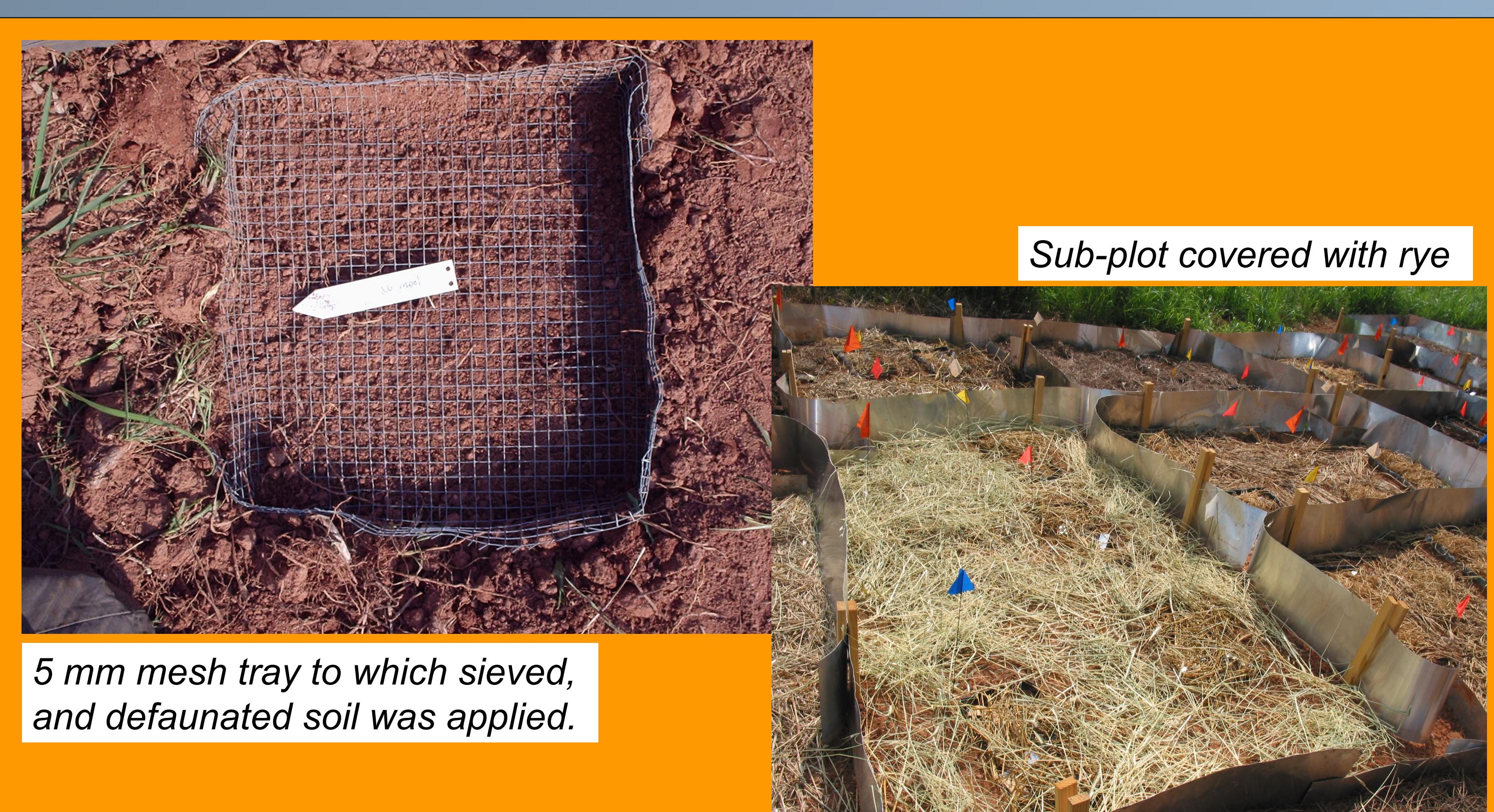
- Although much attention has been given to the amount of resources regulating consumer populations in soil, the quality of resources may be their strongest driver. Understanding the short term effects of plant litter quality on soil detrital food webs is of special importance in integrated agricultural systems where organic soil amendments are seasonally applied as a strategy to enhance fertility. In systems in which plant litter does not get incorporated into the mineral soil or in which incorporation occurs slowly it is crucial to distinguish between the litter communities and the mineral soil communities as (a) they utilize different organic matter pools and thus can different roles in driving processes and (b) the populations that compose them can establish interactions that may influence carbon and nutrient cycling.
- The role of plant litter quality on the structure of soil communities has been addressed by several studies, however, usually responses of populations are studied as a contrast between only two or three substrates (low, high quality, usually with high/low C/N ratio) and other individual quality parameters are not taken into account as specific drivers.
- The quality of surface applied litter has the potential to affect mineral soil communities directly by stimulating/inhibiting populations or indirectly by affecting the physical and chemical characteristics of the mineral soil.
- This study investigates the short term effect that the chemical composition of one-time surface-applied amendments has on the soil microbial and micro and mesofauna community in the mineral soil. We used five different substrates and their mixture representing a gradient of different quality parameters and attempted to determine (a) the effect of substrate type on litter and soil communities and (b) what chemical parameters most influence the soil micro food web groups' abundance during the first six months of decomposition.
- It is reasonable to expect that some quality parameters are more important than others in driving the response of specific members of decomposer community at different times during decomposition.
- Some microbial groups in soil mainly consume fresh organic materials while some groups mainly derive their substrate from more recalcitrant materials in mineral soil. It would be expected that those groups that are supported mainly by materials in the mineral soil will be less affected in the short term by the quality of added substrate.
- Some microbial and faunal groups appear to be bottom-up regulated whereas some are top-down regulated. It is then reasonable to expect that the bottom-up regulated groups and the top-down regulated groups in litter and soil will differ in the magnitude and duration of their short-term response to litter quality.

Methods

- A field study was conducted in a previously abandoned conventional farm in the Piedmont region of Georgia. Standing vegetation was removed from a 100m² plot. The plot was divided into 24 sub-plots of ca. 4m². Soil from the first 5 cm of a randomly located area of 30 x 30 cm within each sub-plot was collected and sieved to 4mm. Soil was then frozen at -80°C for 72 hours to kill fauna and then placed back in the field in metallic trays (35 cm x 35 cm x 5 cm) made of 5mm mesh. Soil was left bare and allowed to re-colonize and stabilize for 2 months. Six quality treatments were randomly assigned to four of the plots and were surface applied at a rate of 327g/m² both to the inside and to the outside of the tray on July 22. Substrates applied were air dried green litter of Cereal Rye, Crimson Clover, and False Indigo (*Amorpha fruticosa* L.); wheat hay, pine needles, and an even mixture of these. Substrates were processed for carbon, nitrogen, total phosphorus, cellulose, hemicellulose, and lignin (Table 1). Soil samples from each tray were collected in August, October and February. Subsequently,
- Microbial carbon in soil was determined using the Chloroform Fumigation Extraction method.
 - Microbial community structure was assessed using Phospholipid Fatty Acid analysis. Phospholipid fatty acid methyl ester concentrations were converted to mole percentage. PLFA community profiles were then subjected to Principal Component Analysis (PCA). Significance of Principal Components was assessed with one-way ANOVAS.
 - Nematodes were extracted from soil using the Baermann funnel method for 72 hours. Total nematode counts to the level of trophic group were performed for each sample.
 - Microarthropods were extracted for four days on Tullgren-type extractors.
 - Soils were extracted for NO₃- and NH₄⁺ by shaking in 20 ml of 2 M KCl for one hour.
 - Nematodes and microarthropods abundance data over time were analyzed by repeated measures ANOVA. Data were log transformed prior to analysis. Pearson correlation coefficients were determined for relationships between litter quality and soil variables and soil community variables.

Table 1. Quality parameters of the six substrates added.

| | %N | %C | C/N | % P | % Cellulose | % Hemicellulose | % Lignin |
|---------------------------------|------|-------|-------|------|-------------|-----------------|----------|
| Rye | 0.70 | 45.04 | 70.34 | 0.19 | 38.04 | 27.95 | 3.99 |
| Clover | 2.02 | 43.28 | 22.42 | 0.50 | 33.36 | 12.07 | 7.97 |
| <i>Amorpha fruticosa</i> leaves | 2.35 | 47.10 | 20.19 | 0.61 | 26.89 | 13.91 | 10.01 |
| Pine | 0.43 | 50.95 | 17.90 | 0.05 | 30.51 | 11.89 | 19.19 |
| Hay | 0.49 | 47.07 | 102.5 | 0.16 | 40.37 | 30.05 | 4.63 |
| Mixture | 1.07 | 46.08 | 46.18 | 0.28 | 35.70 | 19.46 | 10.25 |

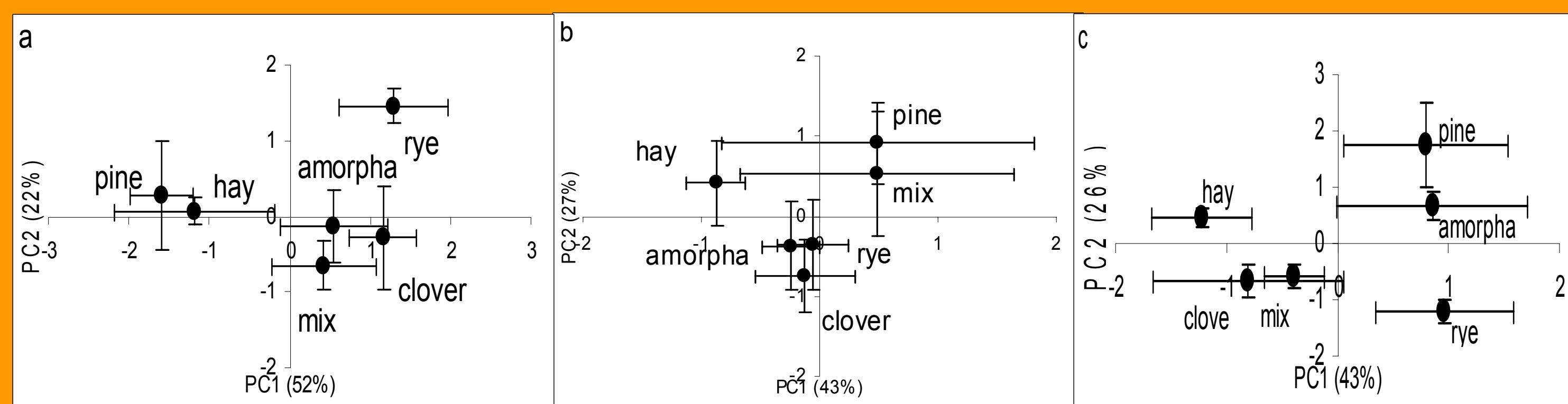


1. Substrate type produced significant differences in soil ammonium and nitrate concentrations but not in soil pH or soil moisture

2. There was no significant effect of substrate type on total PLFAs or soil microbial biomass carbon

3. Different substrates generated distinguishable microbial communities in the mineral soil. Different quality parameters drove the response at different times (Figure 1).

Figure 1. Plot of first and second principal components (PCs) from Principal Component Analysis of %mole of PLFA biomarkers grouped by microbial guild. Data points represent means of 4 replicates +/- 1 standard error. Amount of variability explained by each component is shown in parentheses.



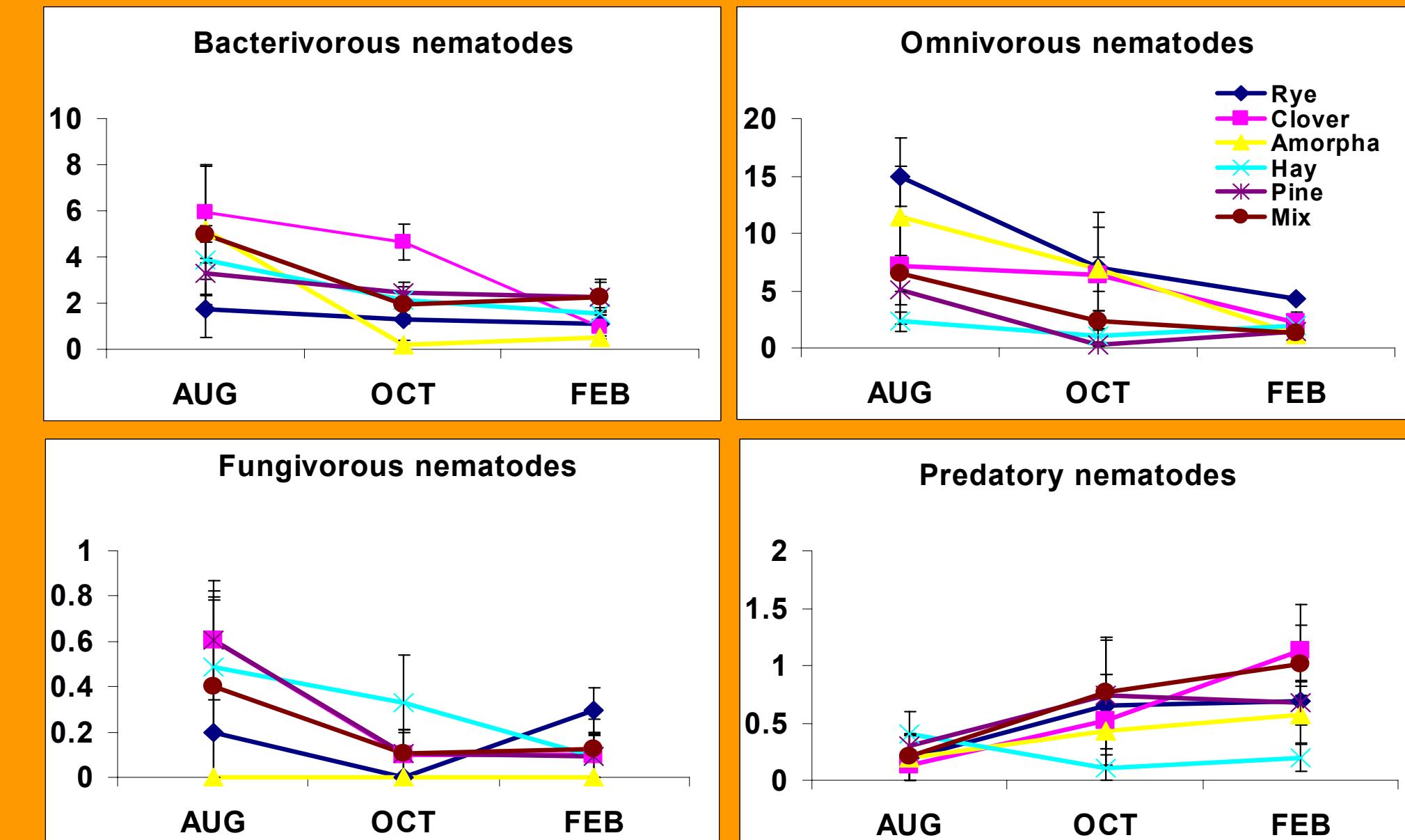
AUGUST: Separation along PC1 strongly correlated with litter %N and %P and soil mineral N.

OCTOBER: PC2 closely correlated with litter %C, %Lignin and Lignin/N

FEBRUARY: %C, %Lignin and Lignin/N were associated with the separation along PC2

4. The bacterivorous, fungivorous and omnivorous nematodes responded to substrate type. The greatest differences occurred after three weeks and then decreased. In contrast, predatory nematodes' response to quality increased with time (Figure 2).

Figure 2. Nematode trophic groups (no./g soil +/- 1 S.E.) in mineral soil over the course of decomposition.



5. No significant responses of collembola, oribatid, prostigmatid or mesostigmatid mites were observed.

6. Microbial and nematode groups showed significant relationships with soil mineral N but these disappear after three weeks. (Table 2).

6b. Soon after the beginning of decomposition there were strong positive correlations between microbial groups and litter N and P and soil N. After 3 and 6 months cellulose, and lignin concentrations showed the strongest relationships.

6c. Bacterivorous and omnivorous nematodes showed significant correlations with litter %N and %C and with bacterial groups and actinomycetes throughout the study.

6d. Both bacterial and fungal populations responded to quality, but bacterial groups responded to more variables and their response lasted longer than that of fungi.

| | | %P | %N | %C | C/N | %Cell | %Lignin | Lign/N | Soil NH4 | Soil NO3 |
|----------|-------------------------|------------------|------------------|-------------------|-------------------|------------------|------------------|------------------|-------------------|------------------|
| 3 weeks | Fungi | -- | -- | -0.52 (0.013) | -0.51 (0.016) | -- | -- | -- | 0.73 (0.0001) | 0.46 (0.032) |
| | Gram + bacteria | -0.43 (0.046) | -0.44 (0.041) | -- | 0.47 (0.028) | -- | -- | -- | -- | 0.50 (0.018) |
| | Gram - bacteria | 0.55 (0.008) | 0.53 (0.011) | -0.55 (0.008) | -0.67 (0.0006) | -- | -- | -- | 0.52 (0.012) | 0.61 (0.003) |
| | Actinomycetes | -- | -- | 0.44 (0.041) | -- | -- | -- | -- | -0.57 (0.006) | -- |
| | F/B | -- | -- | -0.47 (0.0287) | -- | -- | -- | -- | -- | 0.0012 |
| | Bacterivorous nematodes | -- | -- | -- | -- | -- | -- | -- | -- | 0.52 (0.01) |
| | Predatory nematodes | -0.46 (0.026) | -0.44 (0.037) | -- | 0.49 (0.017) | -- | -- | -- | -- | -0.44 (0.035) |
| 12 weeks | Gram - bacteria | -- | -- | -- | -- | -- | -- | -0.43 (0.044) | -0.46 (0.0313) | -- |
| | Omnivorous nematodes | 0.5 (0.004) | 0.58 (0.003) | -0.49 (0.0157) | -0.62 (0.001) | -- | -- | -- | -- | 0.45 (0.026) |
| 29 weeks | Actinomycetes | -- | -- | 0.72 (0.0001) | -- | -0.47 (0.025) | 0.68 (0.0004) | 0.69 (0.0003) | -- | -- |
| | Bacterivorous nematodes | -0.45 (0.030) | -0.47 (0.023) | -- | -- | -- | -- | -- | -- | -- |
| | Predatory nematodes | -- | -- | -0.56 (0.006) | -- | -- | -- | -- | -- | -- |

Discussion

- The effect of quality parameters on the soil microbial populations varied across time. The fact that nutrients had the strongest effect early during decomposition suggests that litter quality affected the community indirectly through the release of mineral nutrients to the soil. In later stages the overall response to quality was smaller but recalcitrant materials had a greater relative effect which suggests that litter quality affected the community by affecting carbon availability.
- The effect of quality on microbial feeding nematodes was only evident at early stages and appeared to be driven by nutrient concentration in litter and soil. This was consistent with the response of the microbial groups.
- Although bacteria are thought to be top-down regulated while fungi are bottom-up regulated, in this study bacteria were responsive to more litter quality parameters than fungi.