Soil Food Webs, Carbon Flow, and Soil Carbon Storage in Legume-Vegetable Rotations

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Summary

Our goal is to evaluate the functional impact of soil food web structure, including microbes, nematodes, and earthworms on soil C dynamics (CO_2 emission, respiration, and soil organic matter (SOM) fractions) in cropping systems that utilize specialty crops in year-round crop biomass production vs. systems that are subject to periodic cropped and non-cropped periods, and in low (conservation tillage (CT)) vs. high levels of disturbance (standard tillage (ST)).

Although MBC tended to be higher in CTCC (continuous cropping) at 0-5 cm during the course of the experiment, MBC in CTCC was relatively similar to that in other treatments at 5-15 cm and 15-30 cm. Ergosterol was significantly higher at 0-5 cm in CTCC than other treatments in Dec. 2003. This indicated that fungi dominated at the soil surface in CTCC, which was consistent with higher MBC at 0-5 cm in CTCC.

Nematode data (Channel index) indicated that there was no consistent difference between bacterial and fungal feeders at the soil surface, even with CTCC. This appears inconsistent with the ergosterol data. In CT plots where C sources are not incorporated, bacteria were concentrated in the surface layer, due possibly to dissolved organic carbon (DOC) or carbon sources previously decomposed by fungi or other biota. Therefore, nematode and ergosterol data were not necessarily inconsistent. The Channel index also indicated that bacteria dominated at deeper depths in ST plots and that residue was decomposed in the deeper layers of the soil profile. Although it has not yet been measured, POM fraction will provide information about how C was stored at different depths in different tillage systems.

Background

The food web is the community of organisms in the soil that are interdependent for sources of C and energy (Phillips et al., 2003). The soil food web regulates the biological transformations of C in the soil, and thus plays an important role in the formation of recalcitrant molecules that are resistant to degradation (Smith, 1979).

Agricultural management can affect soil food web complexity by creating an environment conducive to the activity of sensitive higher trophic levels and by providing sufficient C.

Nematodes. Soil nematodes are sufficiently abundant and functionally diverse to provide excellent indicators of total food web structure and importance (Ferris and Matute, 2003). Since 80% of the multicellular individuals in the soil are nematodes, they influence the structure and function of the food web in many ways.

Hypothesis

Continuous inputs of plant-derived C and N, combined with CT, will build and sustain soil communities that decompose and stabilize soil C. Year-round crop rotations with CT are expected to have more complex food webs and more stabilized soil C fractions due to gradual, reliable C inputs from plants, lack of disruption by tillage, and greater processing, turnover, and protection of C.

References:

Ferris, H. and M. Matute (in press) Structural and functional succession in the nematode fauna of a soil food web. Applied Soil Ecology.

Phillips, D.A., H. Ferris, D.R. Cook and D.R. Strong. 2003. Molecular control points in rhizosphere food webs. Ecology 84:816-826.

Smith, J.L., J.J. Halvorson, and H. Bolton, Jr. 1994. Spatial relationships of soil microbial biomass and C and N mineralization in a semi-arid shrub-steppe ecosystem. Soil Biology and Biochemistry. 26(9): 1151-1159.

Objectives

The **specific goal** of this project is to evaluate the functional impact of soil food web structure, including microbes, nematodes, and earthworms on soil C dynamics (CO_2 emission, respiration, and soil organic matter (SOM) fraction in cropping systems that utilize specialty crops

1) Compare soil food webs and soil C fractions in year-round vs. winter-fallow legume-vegetable rotations, using either CT or ST methods

2) Examine the processes by which soil food webs stabilize and retain soil C by tracking C from ^{13}C-labeled plants to soil organisms and C fractions in CT and ST systems.

Materials and Methods

Field site. Our field site is the Long Term Research in Agricultural Systems (LTRAS) site at University of California Davis. In the spring of 2003, many of the 1-acre plots were established to be managed with either CT vs. ST.

LTRAS experiment plots

Block I				Block II				Block III			
I ST CC	I CT CC	I ST F	I CT F	II ST CC	II CT CC	II CT F	II ST F	III CT F	III ST F	III ST CC	III CT CC

CTCC (Conservation tillage Continuous Cropping)

CTF (Conservation tillage Fallow

STCC (Standard tillage Continuous Cropping)

STF (Standard tillage Fallow)

Crop rotation

	Summer 2003	Fall 2003	Winter/ Spring 2003-04	Summer 2004
Continuous Cropping rotation	Tomato	Sudan & Sorghum Cover Crop	Garbanzo	Cowpea
Fallow Rotation	Tomato	Fallow	Garbanzo	Fallow

Table 1. Winter-legume and winter-fallow rotations conducted at the LTRAS site in Davis. Both rotations included conservation (CT) and standard (ST) tillage treatments

Soil sampling in the field

Dec. 2003; June, Sept., and Dec. 2004.

0-5 cm , 5-15 cm, 15 -30 cm depth

What was measured

Soil : Microbial biomass C (MBC), Ergosterol (a fungal indicator), Total soil C (TOC), Inorganic Nitrogen (NO_3, NH_4), Particulate organic matter fraction (POM).

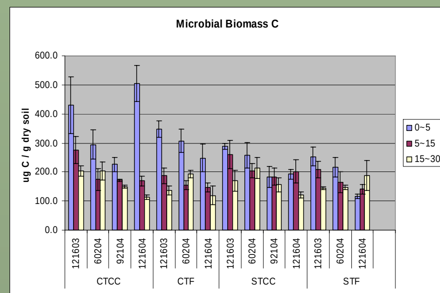
Plant: Aboveground biomass was harvested

Nematodes : Community composition (food web indicator). Identified to family or genus levels.

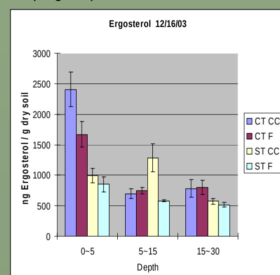
^{13}C glass house experiment: Cowpea plants were labeled with depleted ^{13}C, in a greenhouse at UC Santa Cruz, so that leaf and shoot material had an enrichment of approx. -40 delta units. The fresh shoots were placed on the soil surface (CT) or incorporated to simulate tillage (ST) in soil cylinders. MBC, ergosterol, nematodes, and inorganic nitrogen were sampled at -3, 10, 30 days after adding cowpea residue labeled with ^{13}C.

All treatments in December, 2003: CT CC at the far right and, to the left in 3-bed increments, ST CC, ST F, and CT F in foreground

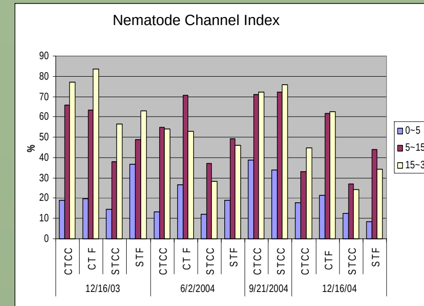
Results



MBC tended to be higher at 0-5 cm in CTCC. However, it was relatively similar below 5 cm depth in all treatments. (ANOVA in progress).



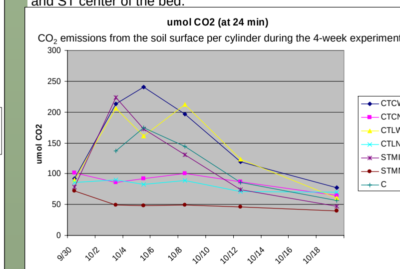
Ergosterol was significantly higher at 0-5 cm in CTCC, indicating that fungi dominated the surface layer in these plots. (Data in progress for Dec. 2005).

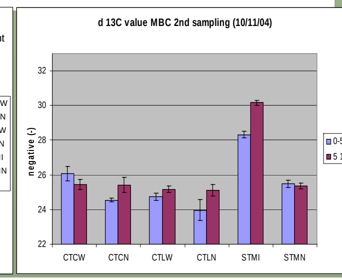


The nematode Channel index (CI) was low at the soil surface in all treatments, indicating that bacterial feeders were associated with bacteria biomass. At greater depths, CT systems were less bacterial than ST systems, as inferred from bacterial feeding nematode populations.

^{13}C microcosm experiment

The **hypothesis** is that soil from the plant row will retain more of the ^{13}C than soil from zones with less accumulated decomposing root material (i.e. center of the beds) because a more complex soil food web is already in place to assimilate and retain the newly-added C. We compared CT CC planting row, CT CC center of the bed, and ST center of the bed.





CTCW (CT + Root + Cowpea residue), CTCN (CT + Root + Non residue), CTLW (CT + Less root + Residue), CTLN (CT + Less root + Non residue)

STMI (ST + Intermediate amount of root + Incorporated residue), STMN (ST + Intermediate amount of root + Non incorporated residue), C (Cowper residue without soil)

Cowpea residue was rapidly decomposed and assimilated by the microbial biomass in the ST treatment, whereas, it was not readily utilized by soil microbes in CT treatments.

Conclusions

•MBC tended to be higher in the 0-5 cm layer with conservation tillage and continuous cropping. However, it was relatively similar below 5 cm depth in all treatments.

•Ergosterol was higher at 0-5 cm with conservation tillage and continuous cropping, indicating more fungi.

• Channel index was low at the surface in all treatments, indicating that bacterial feeders were dominant even with conservation tillage, possibly because decomposition at the surface provided substrates for bacteria.

•Cowpea residue was rapidly decomposed and assimilated into microbial biomass with standard tillage, whereas it was not readily utilized by soil microbes with conservation tillage.

•Cumulative CO_2 emission was higher with conservation tillage, indicating carbon loss without carbon storage. This may be due to residue decomposition by organisms on the leaf surface, and lack of soil contact for assimilation.

•Future plans

•POM fraction will provide information about how C was stored at different depths in different tillage systems.

•Results of ^{13}C experiment will elucidate how C flow is affected by soil food webs.