Partitioning of Soil Respiration into Aboveground and Rhizosphere Components Using $^{13}CO_2$ Labeling in Conventional and Conservation Tillage Vineyard Systems.

David R. Smart[1], Danielle Pierce[1], Kerri L. Steenwerth1,[2] Eli Carlisle[1], Joshua Hunt[2] Geoff Dervishisian[1] and Brian K. Strand[1]
[1]Department of Viticulture & Enology, University of California, One Shields Avenue, Davis CA 95616
[2]USDA-ARS, Crops Pathology and Genetics Research Unit, University of California, One Shields Avenue, Davis CA 95616

Soil carbon (C) sequestration has become a topic of intense national and international interest in ecosystem science with respect to efforts at mitigation of greenhouse gas (GHG) emissions to the atmosphere. Partitioning of ecosystem respiration between new, more labile C pools and recalcitrant C pools is critical to understand carbon sequestration into soils. Previous efforts have used radioactive $^{14}CO_2$ labels or natural abundance levels of ^{13}Cand ^{14}C on soil respired CO_2 to determine age, or partition among C sources being oxidized. During 2004 and 2005 we used $^{13}CO_2$ labeling *in situ* to partition soil respired CO_2 between recently assimilated C and recalcitrant C sources in a vineyard cover crop that was conventionally managed (tilled), and compared it with a conservation tillage system. In order to accomplish our objective we employed Keeling analysis in conjunction with an isotope-mixing model (δ^{13}CT = *fn* δ^{13}Cn + *fo* δ^{13}Co), where CT. is the δ^{13}C label of total soil respired CO_2 and fn and fo are the fractions derived from the more labile (^{13}C labeled) and recalcitrant pools respectively. Rhizosphere respiration was approximately one fifth of above ground respiration in both years. In 2004 moisture levels were low as a consequence of spring drought. Labile C sources were retained in soils throughout the summer in 2004, being strongly oxidized with the onset of autumn precipitation. In contrast to 2004, in 2005 precipitation in April and May greatly increased both soil moisture and 13C loss from both the more labile and recalcitrant pools in both the 2004 labeled and 2005 labeled systems. The quantity of carbon oxidized and emitted by soil respiration following tillage in 2005, when moisture contents were high, was prolonged and challenges previous assumptions concerning the timing and intensity of microbial activity following tillage disturbance. ^{13}C pools retained in 2004 in the conventionally tilled system were predominantly respired following soil wet-up in both 2004 and 2005. Several important observations have emerged from the most recent phase of this work. In addition to showing that $^{13}CO_2$ can be used as a tracer to partition aboveground versus rhizosphere respiration, our results also suggest that soil decomposition will be driven by moisture content in Mediterranean environments, even those with high seasonal rainfall amounts. The influence of climatic change on precipitation patterns and quantities may therefore have a stronger influence on soil organic C dynamics than climate change driven temperature change alone.

Objectives:
Two objectives were used as the basis for this experiment:

1. Determine whether soil respiration rates increased with soil moisture.

2. Quantify the effect of soil disturbance on soil respiration rates.

Isotopes: A barley cover crop (UC 603) in the vineyard was labeled using $^{13}CO_2$ in the spring of 2004 and again, in separate plots, in 2005. Each cover crop treatment (i.e., mowed or tilled treatments) were labeled. After the barley was either mowed or tilled in late-March/early-April, changes in the isotope signal were observed using "Keeling" plots and a two-pool mixing model. This model allowed us to partition the carbon efflux into two pools: 1) new carbon (highly enriched), and 2) old carbon (natural abundant background).

Mass Balance: The *Keeling* (Keeling 1961) linear mixing model was used to estimate the changes in ^{13}C label over time. In this paper, we make the assumption that fO represents older carbon pools and f_N represents the new carbon input from the barley cover crop. This method assumes that the isotopic composition of the CO2 sources remain constant during the sampling period (Miller and Tans 2003, Pataki et al. 2003). The intercepts from the linear mixing models were calculated using geometric mean regression according to Pataki et al.(2003). The CO2 isotope and mixing ratio data were used to partition

the total source into two component parts: old carbon (f_O) and new carbon (f_N). To solve for the contribution of f_O versus f_N we used the following equations.

$$\delta = (R\ sample / R\ standard - 1) * 1000\ ‰ \quad (1)$$

$$f_O + f_N = 1 \quad (2)$$

$$\delta^{13}C_O\ f_O + \delta^{13}C_N\ f_N = \delta^{13}C_S \quad (3)$$

An assumption in these equations is that the f_O and f_N stay constant during the time the samples are taken in order to find δ^{13}CS from equation (3). If this assumption is true, the isotope composition of the background air is not needed to separate the two respiration components, f_O and f_N.

Significant differences between the treatments occurred during disturbance events: 1) tillage vs. mowing the cover crop and 2) soil rewetting. When rain fell on dry and/or after a tillage event, large pulses of increased CO2 efflux occurred.

Soil moisture tended to be more highly correlated to soil respiration than soil temperature. In 2004, soil respiration was low when soil moisture approached 20%. However, during the year 2005, when rainfall was greater and occurred more frequently than in 2004, a different pattern was observed. In 2005, soil respiration and moisture changes oscillated with more frequent precipitation events. Furthermore, a delayed response was observed between increases in soil moisture and respiration was observed.

Conclusions:
The results suggest that the effects of disturbance events like tillage and soil rewetting must be documented in order to provide an accurate assessment of annual soil respiration (see Fig. 1, 2, 3, 4).

The data indicate that sampling frequency and temporal scale can affect assessments of controls on annual soil respiration (Figs. 1, 4). Daily temporal oscillations in soil respiration occur, but this oscillation is not captured in bimonthly measurements. When soil respiration is measured bimonthly, soil moisture is a dominant controlling factor of observed rates. However, when soil respiration is measured over a 24-hour period under constant moisture, soil temperature greatly influences rates.

Soil disturbance due to mowing or tilling had an immediate impact on CO2 lost from the soil. The treatment effects were approximately equal in terms of lost C, depending on soil moisture and rewetting/drying cycles. Soil respiration increased during tillage, but a much larger CO2 pulse was released after the simulated rainfall in the cover crop plots in the fall.

References:
Pataki, D. E., D. R. Bowling, and J. R. Ehleringer. 2003a. Seasonal cycle of carbon dioxide and its isotopic composition in an urban atmosphere: Anthropogenic and biogenic effects. Journal of Geophysical Research-Atmospheres 108.

Pataki, D. E., J. R. Ehleringer, L. B. Flanagan, D. Yakir, D. R. Bowling, C. J. Still, N. Buchmann, J. O. Kaplan, and J. A. Berry. 2003b. The application and interpretation of Keeling plots in terrestrial carbon cycle research. Global Biogeochemical Cycles 17.