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Approaches to Separating Autotrophic and Heterotrophic Contributions to Soil Respiration in Maize-based Agroecosystems

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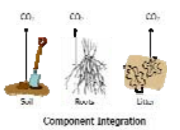
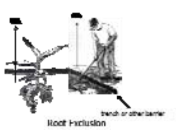
Introduction

We define autotrophic soil respiration (R_a) as combined root respiration and the respiration of soil microorganisms residing in the rhizosphere and using root-derived carbohydrates as an energy source. Heterotrophic respiration (R_h) is defined as the respiration of soil microorganisms and macroorganisms not directly under the influence of the live root system and using soil organic matter (SOM) as an energy source. Approaches to separating R_a and R_h generally fall into three broad categories: component integration, root exclusion, and isotopic approaches (Hanson et al., 2000).



Component integration involves the physical separation of the individual components contributing to soil respiration and measurement of respiration rates for each component. This method may not reflect in situ respiration rates, since the disturbance of the system may modify water-filled pore space (thereby affecting microbial activity), disrupt rhizosphere processes, and alter soil CO_2 concentrations.



Root exclusion involves the indirect estimation of R_a by measuring soil respiration with and without roots. This is accomplished through root removal, trenching (a barrier is created in which existing roots are severed and or new roots are excluded from the area) or gap analysis, in which aboveground vegetation is removed from a large area. The absence of live roots may alter soil moisture, which in turn may affect soil microbial activity. Also, root-excluded soil may have microbial biomass levels that do not reflect field conditions.

Isotopic methods avoid the disturbance of the system associated with the other methods, but labeling of plants with ^{14}C or ^{13}C can be costly and complex, and is difficult to apply in the field. Natural ^{13}C abundance techniques take advantage of the difference between $\delta^{13}C$ values of C_3 plants (-22‰ to -34‰) and C_4 plants (-9‰ to -16‰). R_h reflects the $\delta^{13}C$ of SOM while R_a reflects the $\delta^{13}C$ of living root material. By planting a C_4 crop on soil formed under C_3 crops (or visa versa), R_a and R_h may be estimated based on the $\delta^{13}C$ signature of soil respiration (e.g. Robinson and Scrimgeour, 1995).

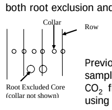
Objectives

The overall objective of this study is to improve our understanding of the specific sources of soil-respired C in production scale (~65 ha) irrigated and rainfed maize-based agroecosystems through the separation of soil respiration into its autotrophic (R_a) and heterotrophic (R_h) sources over the growing season. This effort will provide more accurate daily R_a and R_h estimates than are currently available for use in carbon budget calculations. A secondary objective is to determine the effect of soil moisture and temperature on the partitioning of soil respiration into R_a and R_h in irrigated and rainfed maize-based agroecosystems.

Materials and Methods

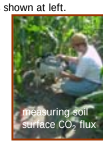
This research is being conducted at University of Nebraska Carbon Sequestration Program (CSP) near Mead, NE. Sampling within each site is carried out in six small intensive measurement zones (IMZs), 20 m x 20 m each, which accommodate the spatial variability in soil properties that may affect soil respiration (e.g. soil type, soil organic matter content, and landscape features affecting soil water content).

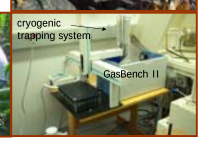
The method we are employing to separate R_a and R_h combines both root exclusion and natural ^{13}C abundance methods.



Collars (8 cm i.d.) are installed in root excluded and non – root excluded soil as shown at left.

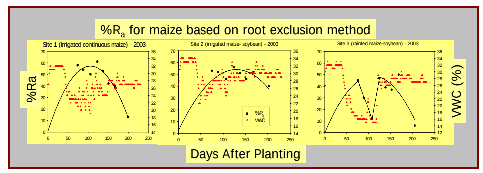
Previous to $\delta^{13}C$ sampling, soil surface CO_2 flux is measured using the LI-6200 Portable Photosynthesis System as shown at the right. Chambers (0.33 L) are then placed on collars, and the headspace within the chamber is pumped through a soda lime trap and a desiccant at 1.5 LPM for 2 minutes to remove ambient CO_2. Chambers are then closed for approximately 35 minutes. Samples are then collected in evacuated 12 mL vials and analyzed for $\delta^{13}C$ using a Delta-S isotope ratio mass spectrometer (Thermo Finnigan, Inc.) interfaced with a Thermo Finnigan GasBench II, whose sample loop has been replaced with a cryogenic trap in order to increase CO_2 concentration before injection into the GC column.



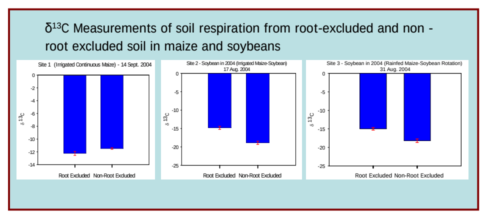


Preliminary Results

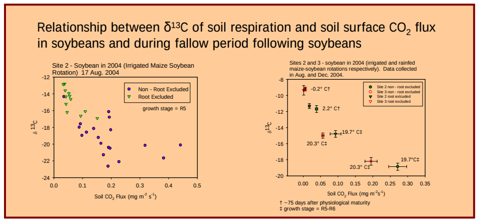
The root exclusion method alone was used to determine the seasonal pattern of $\%R_a$ in irrigated continuous maize and in irrigated maize in rotation with soybean during the 2003 growing season. As can be seen below in the curve for the rainfed site, low soil water content decreases measured $\%R_a$. This may be because the absence of roots in the root excluded cores resulted in a higher %VWC. (Soil water content was not measured within the root excluded cores.)



The figures below show three days of $\delta^{13}C$ sampling of soil respiration in the three sites during the 2004 growing season. While little difference in $\delta^{13}C$ of soil respiration was seen in root excluded and non – root excluded soil in continuous maize, the $\delta^{13}C$ of non - root excluded soil respiration in soybean was considerably more negative, reflecting the more negative $\delta^{13}C$ signature of soybean plant material. The application of $\delta^{13}C$ analysis to the separation of R_a and R_h under natural field conditions has usually been accomplished by growing a C_4 plant on a long term C_3 field (e.g., Rochette and Flanagan, 1997). These results suggest that the natural ^{13}C abundance technique may be applied even if SOM has been formed under a rotation of both C_3 and C_4 plants.



The figure below left shows $\delta^{13}C$ of soil respiration plotted against soil surface CO_2 flux in irrigated soybeans in a maize-soybean rotation. The higher the soil surface CO_2 flux, the more associated it is with root respiration and hence, the $\delta^{13}C$ of the growing crop. The figure on the right shows mean $\delta^{13}C$ of soil respiration vs. mean soil surface CO_2 flux in root excluded and non – root excluded soil in the two soybean fields on two sampling days during the growing season and on two days during the following winter. Soil temperature at the 10 cm depth is included next to the data points. As expected, during the growing season, $\delta^{13}C$ of soil respiration from root excluded soil is clearly distinguished from that of non – root excluded soil. Although soil surface CO_2 flux readings indicated a substantial contribution of root decomposition to soil respiration for the two December sampling days (54% for site 2 and 76% for site 3), the $\delta^{13}C$ values of soil respiration samples collected from root excluded and non – root excluded soil were nearly indistinguishable. In addition, as soil temperature dropped to below freezing and soil surface flux readings approached zero, $\delta^{13}C$ values of soil respiration approached the atmospheric $\delta^{13}C$ value, indicating a limitation of the method when soil respiration rates are extremely low.



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Literature cited:
Hanson, P.J., N.T. Edwards, C.T. Garten, and J.A. Andrews. 2000. Separating root and microbial contributions to soil respiration: A review of methods and observations. Biogeochemistry 48:115-146.
Robinson, D., and C.M. Scrimgeour. 1995. The contribution of plant C to soil CO2 measured using δ13C. Soil Biol. Biochem. 27:1653-1656.
Rochette, P. and L.B. Flanagan. 1997. Quantifying rhizosphere respiration in a corn crop under field conditions. Soil Sci. Soc. Am. J. 61:466-474.