Measurement of CO_2 Exchange in a Peanut field

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1. Response to temperature and soil moisture

Introduction

Peanut (*Arachis hypogaea* L.) is particularly susceptible to water stress of different duration and intensities during the growing season. Water stress becomes a main concern of farmers because of numerous years of drought associated with climate variability and climatic change. The eddy-covariance (EC) technique can provide valuable information on the functional responses of the soil-plant system to environmental factors such as water stress. It is crucial to get more insight into the response of both components of soil respiration to water stress. Autotrophic (*Ra*) and heterotrophic (*Rh*) respiration, however, react differently to changes in environmental conditions. Therefore, partitioning soil respiration will improve our understanding of the peanut's responses to environmental stress leading to recommendation on the water management for better peanut productivity.

Objectives

- to understand the net ecosystem carbon exchange (NEE) response to environmental parameters.
- to understand the separate responses of autotrophic and heterotrophic respiration to environmental parameter.

Methods

EC technique

Site : Non-irrigated peanut field at the SWGA Research and Education Center , Plains, Georgia

Fluxes of CO_2 and water vapor were determined from measurements using a 3D sonic anemometer (CSAT3, Campbell Scientific, Logan, UT) and open-path infrared gas analyzer (LI-7500, LI-COR, Lincoln, NE) mounted 1.5 m above the ground surface (Fig. 1) and sampled at 10 Hz.

Environmental parameters include net radiation, RH, soil water content, soil temperature and soil heat flux were measured. An *in situ* weather station was placed at the site monitoring air temperature and humidity, wind speed and direction, solar radiation and rainfall.

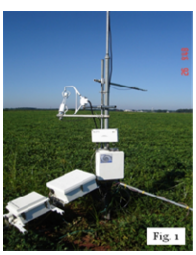


Fig. 1

Soil CO_2 efflux-soil chamber

Fig. 2

Site: Non-irrigated peanut field at Unadilla, Georgia

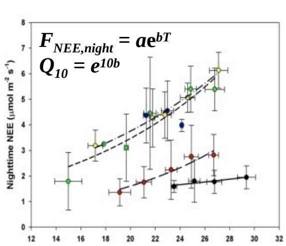
Periodic measurements of soil CO_2 efflux were made using the Li-8100 soil CO_2 flux system (Licor, Lincoln, NE) equipped with a 10 cm survey chamber (Fig.2).

Soil temperature and soil water content at a 5 cm of depth were measured simultaneously as soil CO_2 efflux. By combining the chamber method and the root-exclusion method, we try to separate total soil respiration (*Rs*) into *Ra* and *Rh*.

$$Rs = Ra + Rh$$

Results

NEE



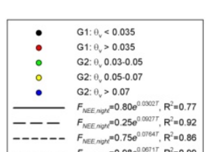


Fig. 3 Relationships between nighttime NEE and air temperature as a function of different growth stages and different ranges of soil moisture.

In the early growing season, $F_{NEE,night}$ increased with temperature and dependened on soil moisture (Fig. 3). After initiation of the peanut flowering period, the function relation of $F_{NEE,night}$ on temperature was independent of soil moisture.

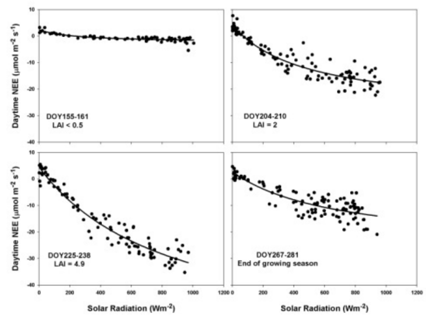


Fig. 4 Examples of light-response curve of daytime NEE at different LAI. Fitted curves are a modified form of the Michaelis-Menten equation.

The dependence of $F_{NEE,day}$ on solar radiation changes with the season; the magnitude of $F_{NEE,day}$ increases as solar radiation increase. The values of $F_{NEE,day}$ increase as LAI increases, when compared with the same values of solar radiation (Fig.4).

Soil CO_2 efflux

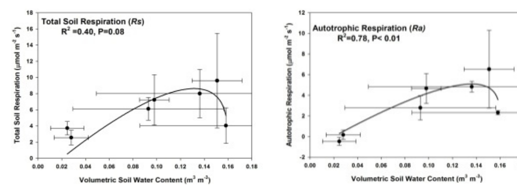
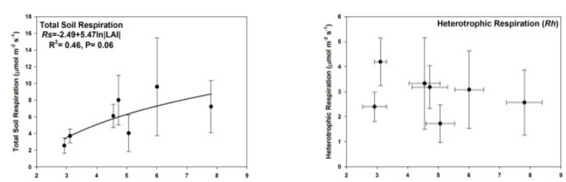
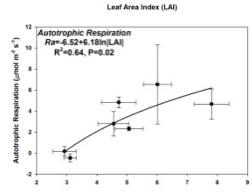


Fig. 5 Response of *Rs* and *Ra* to soil water content.

The maximum *Rs* (8 μmol $m^{-2} s^{-1}$) and *Ra* (5 μmol $m^{-2} s^{-1}$) were predicted at ϑ_v of about 0.135 $m^3 m^{-3}$ and were near zero under extremely dry soil condition. Soil water content at 5 cm depth accounted for 40 and 78% of the seasonal variability in *Rs* and *Ra*, respectively (Fig. 5).





The seasonal variation of LAI correlated with the seasonal variation of *Rs* and *Ra* (R^2 =0.46, 0.64) (Fig. 6), suggesting the timing of photosynthetic activity and subsequent belowground allocation respond to seasonal changes in substrate availability

Fig. 6 Response of (a) *Rs*, (b) *Rh* and (c) *Ra* to LAI.

Conclusions

- $F_{NEE,night}$ was influenced by soil moisture, temperature and peanut growth stage.
- $F_{NEE,day}$ was influenced by solar radiation, soil moisture, and LAI.
- Seasonal variations in *Rs* and *Ra* were linked to variation in LAI, suggesting that photosynthetic activity significantly regulates respiratory release of soil CO_2 from soil.

2. Response to Rainfall Variability

Introduction

Rainfall variability is likely to become a problem associated with climate change, thus rainfall variability may lead to loss of soil carbon. Soil CO_2 efflux, as known as soil respiration, is an important aspect of soil quality and a good indicator of soil fertility. Soil CO_2 efflux is composed of both root and microbial respiration. Root and microbial respiration processes are likely to respond to increase in rainfall variability in different ways. However, the mechanisms underlying the variability of soil CO_2 efflux following rainfall are still poorly understood due to difficulty in making reliable soil CO_2 measurements in a short crop. Moreover, quantifying how soil CO_2 efflux responds to rainfall variability and environmental change has not been determined in peanut field.

Objectives

❖To examine seasonal pattern of soil CO_2 efflux in peanut field

❖To examine the mechanisms of soil CO_2 efflux following rainfall

Materials & Methods

The study site was located at the University of Georgia's Southwest Georgia Research and Education Center in Plains, Georgia.

Soil CO2 efflux was continuously measured during May-September 2007: Peanut (*Arachis hypogaea L.)* with irrigation.

Soil CO_2 efflux: automated chamber method

Soil surface CO_2 flux was continuously measured at one location in peanut field using a 20.3 cm long-term a soil automated chamber (Li-8100-101).

Soil temperature and volumetric soil water content were measured continuously with the efflux and recorded on a CR1000 datalogger.

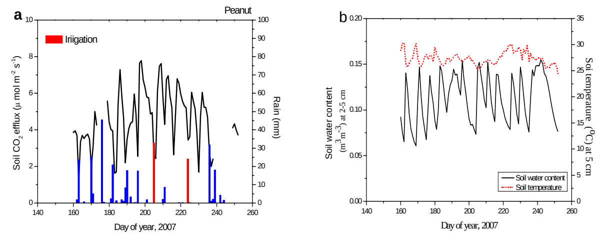
Conclusions

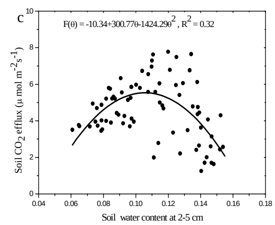
1. The change in total soil CO_2 efflux was mainly control by soil water content.

2. The enhancement of soil CO_2 efflux after rainfall is related to soil water content. The increase in soil water content may make the physical environment favorable to microbial activity.

Results:

1. Seasonal variability of soil CO_2 efflux, soil temperature and soil water content.

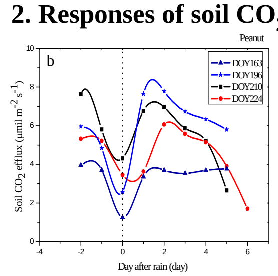




❖Soil water content had strong influence on daily total soil CO_2 efflux, but soil temperature had a little correlation with daily total soil CO_2 efflux.

Soil water content had two opposite direction influencing soil CO_2 flux. When soil water content was below 0.105 $m^3\ m^{-3}$, soil CO_2 increased with soil water content increased; It decreased with soil water content greater than 0.105 $m^3\ m^{-3}$.

2. Responses of soil CO_2 efflux to rainfall



❖During rainfall, daily soil CO_2 efflux decreased because high soil water content at surface layer decreased soil air porosity and oxygen availability in soil.

❖Soil CO_2 efflux immediately increases after rainfall and then declines to the pre-rainfall value.

We developed an exponential decay model to quantify the decrement of soil CO_2 efflux to the pre-rainfall value of soil CO_2 efflux after rainfall.

$$F = F_0 + a\left(\frac{t}{\tau}\right)^2 e^{-\left(\frac{t}{\tau}\right)}$$

F is soil CO_2 efflux after rain (μmol $m^{-2}\ s^{-1}$),
Fo is base respiration (μmol $m^{-2} s^{-1}$);
t is number of days after the rain event;
a is enhancement (-);
τ is the time required for *F* to decline of its peak value (days)

Table 1. The parameters of exponential decay model in peanut field. Increase (%) = Increase in soil CO_2 efflux due to rainfall event.

Rainfall events	*F0*	A	τ	r2	Increase (%)
DOY163 (25.22mm)	1.72	4.22	1.47	0.78	196
DOY196 (17.53mm)	3.49	8.83	0.99	0.83	202
DOY210 (10.66mm)	3.60	6.90	0.76	0.79	61
DOY224 (24.18mm)	2.30	6.41	1.12	0.67	76

❖the enhancement of soil CO_2 efflux after rainfall was higher for higher amount of rainfall event and than, the decrement of soil CO_2 to the pre-rainfall value was slower as compared with smaller amount of rainfall event.

❖The decrement of soil CO_2 efflux to the pre-rainfall value in the peanut field was positively correlated with the amount of rainfall.