10.2 SEASONAL INTERACTIONS BETWEEN CARBON DIOXIDE AND WATER VAPOR FLUX IN CORN CANOPIES

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## 1. INTRODUCTION

Transpiration of water vapor from plant leavers into the atmosphere is critical for cooling leaves. The greater the amount of water transpired during the season the greater the potential production of plant biomass. Water vapor transfer to the atmosphere occurs through the stomata and these pores provide for the entry of carbon dioxide into the leaf. Carbon dioxide and water vapor are two critical components related to plant growth. Until recent advances in measurement methods it has been impossible to develop season-long measurements of both of these gases above and within plant canopies. The insights we can gain from measurement of both $CO_2$ and $H_2O$ vapor fluxes above and within the canopy can provide a more complete understanding of these interactions and the relationship to crop microclimate. The objective of this study is to quantify $CO_2$ and $H_2O$ vapor fluxes in corn and soybean canopies grown under different management practices.

## 2. BACKGROUND

A physiological basis for water use efficiency was developed from some early work by Bierhuizen and Slatyer (1965). They showed that $CO_2$ uptake within a plant canopy, $N_c$, could be described by the following relationship:

$$N_c = (cC_a/1.5)\left[\begin{array}{l} LAI/(r_b + r_s)_D \\ +(LAI - LAI_D)/(r_b + r_s)_o \end{array}\right] \quad (1)$$

where c = 0.7 for corn, $C_a$ the $CO_2$ concentration in the air, LAI the leaf area index of the canopy, $r_b$ the boundary layer resistance (s m$^{-1}$), $r_s$ the stomatal resistance (s m$^{-1}$), and subscripts D representing leaves in direct sunlight and o representing the leaves in shade.

We can use a similar relationship to describe transpiration, $T_c$, from a plant canopy as

$$T_c = \left(\frac{\rho\varepsilon}{P}\right)\left[\begin{array}{l} LAI_D\dfrac{(e_D^* - e)}{(r_b + r_s)_D} \\ +(LAI - LAI_D)\dfrac{(e_o^* - e)}{(r_b + r_s)_o} \end{array}\right] \quad (2)$$

where $\rho$ is the density of air, $\varepsilon$ the ratio of the molecular weight of water vapor to dry air, P the atmospheric pressure, e the water vapor density in the air, and e* the saturation vapor pressure of the air. This approach can be used to determine the relative contributions of different layers of the plant canopy to the total transpiration or $CO_2$ flux. (Sinclair et al, 1976). These equations have been tested on a number of different canopies with acceptable results. The ratio of $N_c/T_c$ can be utilized to examine the instantaneous water use efficiency of plant canopies under a range of management practices. With the development of instrumentation to measure $CO_2$ and $H_2O$ vapor fluxes across a range of conditions the approach given through Equations 1 and 2 can begin to provide new insights into canopy processes.

## 3. EXPERIMENTAL APPROACH

Experiments have been conducted on corn and soybean canopies grown in production sized fields since 1998. The overall purpose of the experiment has been to quantify the response of both crops to management practices. The field size is 60 ha with half in each crop. Management practices are placed with the north-south row direction and generally only three different management practices are evaluated each year. Within each management practices a range of soil types was present and measurements of crop response and microclimatic parameters were made in selected areas of the field.

Microclimatic measurements consisted of net radiation, soil heat flux, soil temperature, water

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vapor, air temperature, windspeed, and surface temperature. Net radiation was measured at 2 m above the canopy, soil heat flux at 0.1 m below the soil surface at three positions, and soil temperature at depths of 0.01, 0.02, 0.05, 0.1, 0.2 and 0.5 m. Windspeed was measured at 0.5 and 1.25 m above the canopy along with air temperature from an shielded, aspirated Visalia humidity probe. In 1999 we added a three-dimensional sonic anemometer to compliment the flux measurements and in 2000 a LI-7500 to measure $CO_2$ and $H_2O$ vapor fluxes. Surface temperatures were measured with an infrared thermometer positioned to view the canopy at a 45° angle from nadir. In 2001 we were able to add an additional system to measure the $CO_2$ and $H_2O$ vapor fluxes at eight positions within the canopy using a multi-port LI6262 system. These data were recorded on a data acquisition system with scan intervals of 10 seconds and an averaging period of 30 minutes. Instrumentation was placed in the field after harvest and remained in place until crop maturity.

Data analyses for this study combined the $CO_2$ and $H_2O$ vapor fluxes within the canopy to determine the potential utility of using this approach to quantify the interactions of $CO_2$ and $H_2O$ vapor fluxes during portions of the growing season.

## 4. RESULTS

Data collected from these studies revealed the interactions that occur between $CO_2$ and $H_2O$ vapor throughout a day. A typical profile of these fluxes is shown in Figure 1.

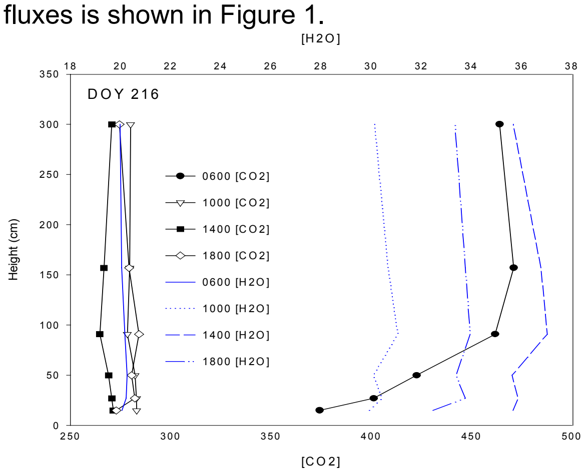


Figure 1. Variation of $CO_2$ and $H_2O$ vapor within a corn canopy on Day-Of-Year 216 every four hours.

There was a large change in $CO_2$ concentrations throughout the day with the highest concentration at 0600 and decreasing rapidly as sunlight began to penetrate the canopy. We observed that the profiles of both $CO_2$ and $H_2O$ vapor changed dramatically during the day. Water vapor increased as the $CO_2$ decreased during the day. During the nighttime the $CO_2$ concentrations increased due to canopy and soil respiration and concentrations at the 0.5 to 1.5 m interval exceeded 700 ppm just prior to sunrise.

During the early morning hours there were a wide range of shapes of the $CO_2$ and $H_2O$ vapor profiles. There were days with little gradient with height in the canopy volume as shown in Figure 2. Over a four-hour period there was a 50 ppm decrease in $CO_2$ concentration and an increase of 7 mg $m^{-2}$ $hr^{-1}$ in $H_2O$ vapor.

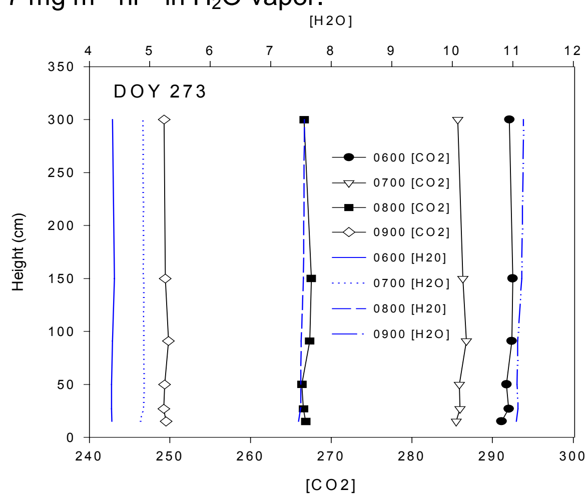


Figure 2. Variation of $CO_2$ and $H_2O$ vapor within a corn canopy on Day-Of-Year 273 in early morning.

These data can be used to evaluate the relationships of canopy microclimate to fluxes of the two gases critical for plant response. Using these data throughout the day we could begin to determine when changes in water use efficiency were being affected by environmental factors. There are opportunities with these measurements to define these responses at shorter time intervals than previously possible.

## 5. REFERENCES


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