Effects of Conventional Tillage and No-Tillage on Crop Gas Exchange Under Elevated Atmospheric CO_2 Conditions

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ABSTRACT

Increasing atmospheric CO_2 concentration has led to concerns about potential effects on production agriculture. In the fall of 1997, a study was initiated to compare the response of two crop management systems (conventional and conservation) to elevated CO_2. The study used a split-plot design replicated three times with two management systems as main plots and two atmospheric CO_2 levels (ambient and twice ambient) as split-plots using open top chambers on a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudults). The conventional system was a grain sorghum [*Sorghum bicolor* (L.) Moench.] and soybean [*Glycine max* (L.) Merr.] rotation with winter fallow and spring tillage practices. In the conservation system, sorghum and soybean were rotated and three cover crops were used [crimson clover (*Trifolium incarnatum* L.), sunn hemp (*Crotalaria juncea* L.), and wheat (*Triticum aestivum* L.)] under no-tillage practices. The effect of management and CO_2 level on leaf level gas exchange during row crop (sorghum and soybean) reproductive growth over multiple growing seasons were evaluated. Treatment effects were fairly consistent across years. In general, higher photosynthetic rates were observed under CO_2 enrichment (more so with soybean) regardless of residue management practice. Further, elevated CO_2 led to decreases in stomatal conductance and transpiration, and water use efficiency was increased. Management had little effect on gas exchange measurements. These results suggest that better soil moisture conservation and high rates of photosynthesis can occur in both tillage systems in CO_2-enriched environments during reproductive growth.

INTRODUCTION

Over the last decade, numerous studies have demonstrated that elevated atmospheric CO_2 often enhances plant water use efficiency, net photosynthesis, and biomass production (Amthor, 1995). The effect of elevated CO_2 on crop residue production can influence soil C dynamics in agroecosystems (Rogers et al., 1999; Torbert et al., 2000). Furthermore, C dynamics can be altered by management practices (Kern and Johnson, 1993; Potter et al., 1998). There is a lack of information on how elevated CO_2 will interact with management practices, especially the newer ones being used in conservation systems. Systems that maintain high levels of residue can help mitigate problems by enhancing soil C storage and soil water holding capacity, reducing evaporative soil water loss, and improving soil water infiltration. Crop growth is often reduced under soil water deficits owing to decreases in photosynthesis, stomatal aperture, and water potential (Boyer, 1982) during critical reproductive stages when demand for water is high. The effect of elevated CO_2 in the field may depend on the crop species utilized; C_3 and C_4 crops such as soybean and sorghum represent two photosynthetic types which are known to respond differentially to elevated CO_2 both with regard to carbon metabolism and water use (Rogers et al., 1983b; Amthor, 1995).

In the current study, crops were grown in a large outdoor soil bin under two different atmospheric CO_2 environments (ambient and twice ambient) and management conditions (conventional tillage and conservation tillage). The objective was to investigate the effect of management and CO_2 level on leaf level gas exchange during row crop (sorghum and soybean) reproductive growth over multiple growing seasons.

MATERIALS AND METHODS

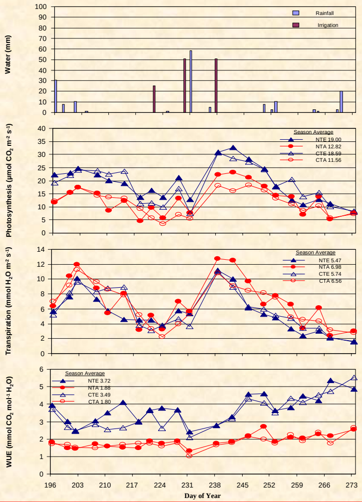
This study was initiated in the fall of 1997 using an outdoor soil bin (7m x 76 m) at the USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama, USA (Batchelor, 1984). A split-plot design replicated three times was used with two cropping systems (conventional and conservation) as main plots and two CO_2 levels (ambient and twice ambient) as subplots using open top field chambers (Rogers et al., 1983a) on a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudults).

In the conventional system, grain sorghum and soybean were rotated each year with spring tillage after winter fallow. In the conservation system, grain sorghum and soybean were also rotated, but with three winter cover crops (crimson clover, sunn hemp, and wheat) which were also rotated; all were grown using "no-tillage" practices. The wheat served as cover as well as being harvested for grain. Cover crops were broadcast planted while row crop seeds were planted on 0.38 m row spacing. Extension recommendations were used in managing the crops.

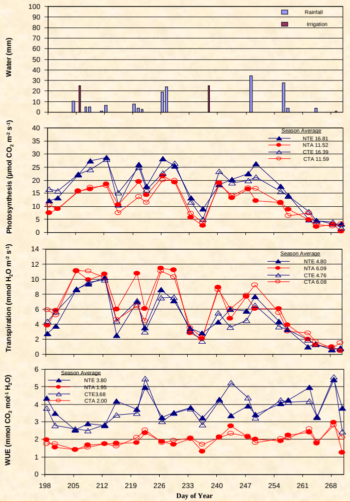
At final harvest, plants were removed and total fresh weights recorded. A subsample of the non-yield material (residue) was taken and its fresh weight recorded; the subsample was dried (55 ^oC) and total residue was calculated using the fresh weight to dry weight ratios (Prior et al., 2005). The remaining residue material was returned to each plot. For grain crops (sorghum, soybean, and wheat), yields were determined following correction for moisture. In the conventional system (after fallow period), weed dry weight was measured as described above and residue was returned to plots prior to tillage.

During reproductive growth, leaf level measurements (i.e., photosynthesis, stomatal conductance (data not shown), and transpiration) were made twice a week using a LI-6400 Portable Photosynthesis System (LI-COR, Inc., Lincoln, NE). Measurements were taken at midday on three different randomly chosen leaves (fully expanded, sun exposed leaves at the canopy top) per plot and were initiated at the start of reproductive growth. Also during this period, soil water status was monitored at two depths (20 and 40 cm) using time domain reflectometry (data not shown).

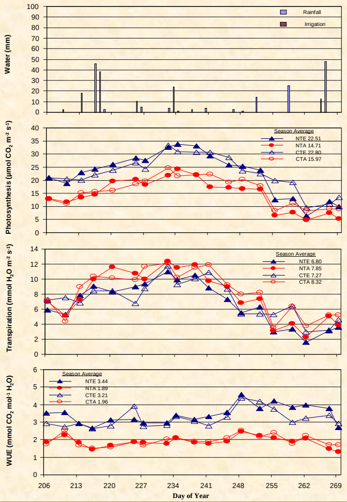
SOYBEAN 1999



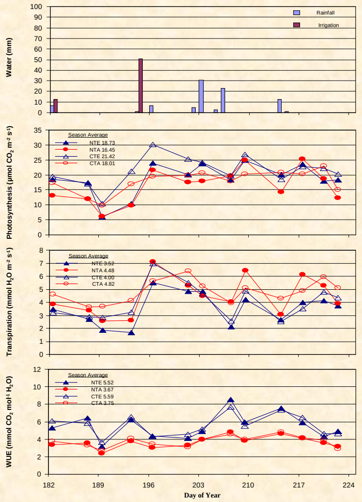
SOYBEAN 2001



SOYBEAN 2003



SORGHUM 2000



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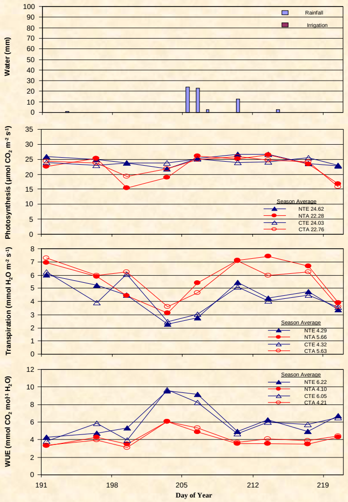

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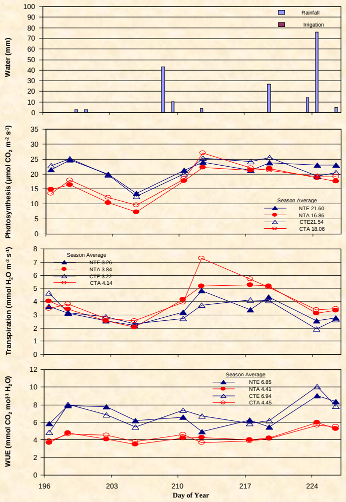

RESULTS AND CONCLUSIONS

- ✓ Elevated CO_2 increased soybean photosynthesis (~50%) across years, regardless of management system used
- ✓ Sorghum photosynthesis was also increased across years in both systems, but to a lesser extent (~15%) than soybean
- ✓ As opposed to photosynthesis, soybean transpiration was more variable; elevated CO_2 decreased transpiration (~17%) across years in both systems
- ✓ The effect of elevated CO_2 on sorghum transpiration was more consistent; elevated CO_2 decreased transpiration (~26%) across years in both systems
- ✓ Due to changes in photosynthesis and transpiration, elevated CO_2 increased water use efficiency for both soybean (86%) and sorghum (51%) across years in both systems
- ✓ In general, management had little effect on gas exchange measurements
- ✓ These results suggest that in a future CO_2-enriched environment better soil moisture conservation and high rates of photosynthesis can lead to increased productivity in both conventional and conservation tillage systems

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