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677 South Segoe Rd., Madison, WI 53711 USA

Free-air Carbon Dioxide Enrichment of Wheat: Soil Carbon and Nitrogen Dynamics

S. A. Prior,* H. A. Torbert, G. B. Runion, H. H. Rogers, C. W. Wood, B. A. Kimball,
R. L. LaMorte, P. J. Pinter, and G. W. Wall

ABSTRACT

The predicted positive impact of elevated atmospheric carbon dioxide (CO_2) concentration on crop biomass production suggests that more C will reach the soil. An aspect of soil C sequestration that requires further study is the effect of elevated CO_2 on C and N dynamics; this relationship is the key to understanding potential long-term C storage in soil. Soil samples (0–5, 5–10, and 10–20 cm increments) were collected after 2 yr of wheat (*Triticum aestivum* L.) production under two CO_2 levels [370 (ambient) and 550 μL L^{-1} (free-air CO_2 enrichment)(FACE)] and two water treatments [100% of ET replaced (wet) and 50% of ET replaced (dry)] on a Trix clay loam [fine, loamy, mixed (calcareous), hyperthermic Typic Torrifluvents] at Maricopa, AZ. Organic C, total N, potential C and N mineralization, and C turnover were determined during a 60-d incubation study. Organic C content increased at all three soil depths under FACE and the total N content increased at the 5 to 10 and 10 to 20 cm depths. In general, increased N mineralization under dry conditions corresponded well with patterns of higher C mineralization and turnover. Nitrogen mineralization was unaffected by CO_2 treatment, indicating that factors other than N may limit C mineralization and turnover. Soil respiration and C turnover patterns were not affected by CO_2 treatment level at the 0 to 5 cm depth; however, these measures were lower under FACE at the lower depths. Soil respiration and C turnover at the 10 to 20 cm depth were increased by water stress under ambient CO_2; these measures under both water levels for FACE were similar to the ambient CO_2/wet treatment, suggesting that more C storage in wheat cropping systems is likely under elevated CO_2 regardless of water treatment.

The well-documented rise in atmospheric CO_2 (Keeling et al., 1989), aside from causing much debate about potential changes to the Earth's climate (e.g., global warming), has raised questions on whether increasing CO_2 will affect the terrestrial C cycle. Carbon fluxes between the atmosphere and terrestrial ecosystems are known to be large (Amthor, 1995). An important question centers on the unbalanced global C budget (Schlesinger, 1991) and on whether plant growth stimulated by CO_2 enrichment will translate into greater soil C storage. Carbon storage by agricultural vs. natural ecosystems may not be large on a relative scale (Amthor, 1995). However, shifts in C storage patterns (e.g., soil organic matter build-up and surface residue residence times) may have important implications for factors (e.g., nutrient cycling, soil-borne diseases, weeds, and erosion) which will affect management decisions made to maintain crop productivity.

Studies have shown that elevated atmospheric CO_2 can increase biomass production both aboveground (Kimball, 1983; Strain and Cure, 1985; Rogers and Dahlman, 1993) and belowground (Rogers et al., 1994), and can alter the chemical make-up of plant tissue, for example, C/N ratios (Conroy, 1992; Rogers et al., 1994). Changes in the quantity and quality of residue due to increased CO_2 will influence soil C and nutrient cycling in terrestrial ecosystems through the process of decomposition. Ultimately, the composition of plant material and nutrients supplied from exogenous sources will influence the rate and extent of organic C turnover, thereby controlling soil C storage patterns (Polglase and Wang, 1992; Torbert et al., 1995).

There has been much discussion on the potential of terrestrial ecosystems to store C, but experimental evidence is lacking. Lamborg et al. (1983) suggested soil C storage would not occur in a world of elevated CO_2 due to increased organic matter decomposition by accelerated soil microbial activity. In contrast, Bazzaz (1990) hypothesized that enhanced soil C storage is likely since decomposition rates would be slower in a high CO_2 environment as a result of increased C/N ratios. It is important to consider that lower tissue N concentration induced by high CO_2, which often increases tissue C/N ratios, may alter soil N dynamics. This can affect decomposition by reducing N availability (Torbert et al., 1995) that may limit plant response to CO_2 enrichment and, thus, long-term C storage (Strain and Cure, 1985).

In addition to C/N ratios, fundamental changes in plant structure (e.g., lignin), cellular composition (e.g., sugars, proteins), and exudates will influence decomposition. Conroy (1992) suggested that plant material grown under elevated CO_2 may decompose faster due to lower lignin/N and lignin/P ratios of plant material despite a higher C/N ratio. Torbert et al. (1995) reported that cotton (*Gossypium hirsutum* L.) plant parts grown under CO_2 enrichment had higher C/N ratios, but the proportion of microbial-resistant plant material decreased. Residue decomposition was similar to that found for plant material grown under ambient CO_2 conditions. They also emphasized the importance of the soil N supplying characteristics on decomposition. An alternative hypothesis was offered by Goudriaan and de Ruiter (1983). They suggested that increased inputs of soluble, easily decomposed C material produced under CO_2-enriched conditions would be the preferred substrate for soil microbes; the result would be reduced decomposition of plant residue and native soil organic matter with subsequent accumulation of soil organic matter. Experimental evidence based on a short-term

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S.A. Prior, USDA-ARS National Soil Dynamics Laboratory, Box 3439, Auburn, AL 36831-3439; H.A. Torbert, USDA-ARS Grassland, Soil and Water Research Laboratory, 808 East Blackland Rd.,Temple, TX 76502; G.B. Runion, School of Forestry, Auburn University, Auburn, AL 36849; H.H. Rogers, USDA-ARS National Soil Dynamics Laboratory, Box 3439, Auburn, AL 36831-3439; C.W. Wood, Department of Agronomy and Soils, 202 Funchess Hall, Auburn University, Auburn, AL 36849-5412; B.A. Kimball, R.L. Lamorte, P.J. Pinter, and G.W. Wall, USDA-ARS U.S. Water Conservation Laboratory, 4331 E. Broadway Rd., Phoenix, AZ 85040. Received 12 Apr. 1996. *Corresponding author (sprior@acesag.auburn.edu.).

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Abbreviations: FACE, free-air CO_2 enrichment; GLM, general linear model.

CO_2 study in growth chambers supports this view (Lekkerkerk et al., 1990). A field study with cotton has suggested that soil C storage is more likely under nonlimiting soil water conditions when CO_2 concentration is raised (Wood et al., 1994). Their findings regarding potential C and N mineralization indicated that factors other than total biomass input may have affected soil C cycling within a FACE cotton experiment. A possible explanation of their results may be related to a differential effect of CO_2 and irrigation treatment on residue structure/composition that altered decomposition patterns.

More field work investigating elevated CO_2 and its interaction with other environmental factors is needed to accurately determine whether shifts in quantity and quality of crop residue will influence C storage, nutrient cycling, and future soil management decisions in agroecosystems. The objective of this study was to investigate the cumulative effect of 2 yr of FACE and soil water stress in a wheat production system on soil organic N and C mineralization and C turnover.

MATERIALS AND METHODS

A FACE system (Hendrey et al., 1993) was used to achieve CO_2 exposure at the 550 $\mu L\ L^{-1}$ level under field conditions for two wheat-growing seasons (1992–1993 and 1993–1994). A large diameter (22-m) PVC torus, fitted with a uniformly spaced series of 32 individually valved vertical vent pipes (2 m height), was used for controlled release of CO_2. Exposure within these circular arrays was regulated by a computer program based on an algorithm keyed to wind velocity, wind direction, and CO_2 concentration. Carbon dioxide was added upwind from open sectors of vent pipes in amounts equivalent to wind speed such that the circular plot within the array was uniformly fumigated. Carbon dioxide exposure commenced after planting each year and was terminated at harvest. Dummy arrays encompassed wheat grown under ambient CO_2 (370 $\mu L\ L^{-1}$). Four FACE and four ambient plots were established.

The soil series at the study site located at the Maricopa Agriculture Center for Resources and Extension of the University of Arizona at Maricopa (33°10 N, 112°0 W) is a Trix clay loam [fine, loamy, mixed (calcareous), hyperthermic Typic Torrifluvents]. Spring wheat (*Triticum aestivum* L. cv. Yecora rojo) was grown according to recommended practices of the state cooperative extension and university research staff. Sowing occurred (mid-December in 1992 and 1993) with a 0.25 m row spacing. All CO_2 plots were irrigated with subsurface microirrigation tubing buried at 0.22 m and spaced 0.51 m apart; plots were split to impose two irrigation regimes. Wet plots were irrigated according to consumptive water use requirements estimated from daily potential evapotranspiration multiplied by a crop coefficient for wheat. Dry plots received 50% less water relative to wet plots at irrigation. Irrigation amounts from emergence to harvest averaged 600 mm for the wet treatment in each year; irrigation amounts over the same period for the dry treatment were 275 and 257 mm for each respective year. Rainfall amounts for each respective season were 123 and 61 mm. Fertilizer was applied at 214 kg N ha^{-1} and 24 kg P ha^{-1}. The effects of experimental treatments on biomass production were very consistent over both years (Pinter et al., 1993, 1994). Biomass production, regardless of CO_2 treatment, was reduced by an average of 28% due to water stress; the wet irrigation treatments under FACE exhibited an estimated 10% increase in biomass relative to their ambient counterparts, whereas dry irrigation treatments under FACE showed approximately a 20% increase.

Soil samples were collected from the study site to investigate the cumulative effect of 2 yr of FACE and water treatments on soil microbial activity. Composite soil samples were collected on 25 May 1994 at harvest. A total of 25 random soil cores were collected per plot at 0 to 5, 5 to 10, and 10 to 20 cm depth increments, stored (5°C), transported by plane to Temple, TX, and processed for the incubation study within 2 d. Methods used by Wood et al. (1994) were used for determinations of potential C and N mineralization. Preincubation soil samples were dried (60°C) and ground to pass a 0.15 mm sieve and analyzed for total N (Fison NA1500 CN Analyzer; Fison Instruments Inc., Beverly, MA). Soil organic C was determined with a LECO CR12 Carbon Determinator (LECO Corp., Augusta, GA; Chichester and Chaison, 1992). Soil inorganic N (NO_2–N + NO_3–N and NH_4–N) was extracted with 2 *M* KCl and measured (before and after incubation) by standard colorimetric procedures using a Technicon Autoanalyzer (Technicon Industrial Systems, 1973a,b). Sieved soil samples (2 mm sieve) were weighed (25 g dry weight basis) and placed in plastic containers. Deionized water was added to adjust soil water content to -20 kPa at a bulk density of 1.3 Mg m^{-3}. Containers were placed in sealed glass jars with 20 mL of water (humidity control) and a 20 mL vial of 1 *M* NaOH (CO_2 trap). Jars were incubated in the dark at 25°C and removed after 30 and 60 d. Carbon dioxide in NaOH traps was determined by titrating excess base with 1 *M* HCl in the presence of $BaCl_2$. Potential C mineralization was the difference between CO_2–C captured in sample traps and in blanks. Potential N mineralization was the difference between final and initial inorganic N contents for the incubation. Potential C mineralization divided by total organic C was used to calculate C turnover.

The experimental design was a split-plot with a randomized complete block arrangement of the main-plot factor (two CO_2 levels; ambient and FACE) for which there were four blocks. The second factor (water regime; wet and dry) was assigned to subplots (each half of the study plot within main plots). Data were analyzed by general linear model (GLM) using the Statistical Analysis System (SAS, 1985). The significance level for all statistical analyses in this study, $P \leq 0.10$, was established a priori.

RESULTS

Initial Soil Characteristics

Initial values for soil total N, organic C, and C/N ratio as affected by atmospheric CO_2 and irrigation treatments are shown in Table 1. Organic C under the dry treatment (0–5 cm depth) was significantly higher relative to the wet conditions. At all depths, the wet treatment exhibited higher organic N levels. Organic C was significantly increased by FACE at all soil depths relative to the ambient CO_2 treatment, while the total N content was increased at the 5 to 10 and 10 to 20 cm depths. The soil C/N ratio was only affected by treatments at the 0 to 5 cm depth; this measure was increased by dry irrigation and by FACE. In general, these results agreed with those reported for soils after 3 yr of FACE in cotton production for soil organic C (Wood et al., 1994); soil organic C was significantly increased in FACE compared to ambient, but organic N was not affected by FACE and changes in soil C/N ratio were not reported in their study.

Net Nitrogen Mineralization

No significant effect of CO_2 treatment and no interactive effects with water treatment were observed for

Table 1. Initial soil organic C and N and C/N ratio as affected by atmospheric CO_2 level and irrigation treatment. Main effect treatment means are shown.

	Irrigation			CO_2 Level			CO_2 × Irrigation
Depth	Dry	Wet	$P > F$†	Ambient	FACE‡	$P > F$	$P > F$
				Organic C, g kg^{-1}			
0–5 cm	10.09	9.19	0.07	8.99	10.29	0.10	0.27
5–10 cm	6.75	7.05	0.60	6.47	7.34	0.03	0.87
10–20 cm	5.47	5.59	0.61	5.25	5.82	0.01	0.23
				Organic N, g kg^{-1}			
0–5 cm	1.05	1.10	0.02	1.07	1.08	0.83	0.62
5–10 cm	0.83	0.94	0.03	0.85	0.92	0.04	0.34
10–20 cm	0.69	0.74	0.08	0.69	0.74	0.07	0.47
				C/N ratio			
0–5 cm	9.62	8.36	0.02	8.40	9.57	0.03	0.19
5–10 cm	8.14	7.54	0.27	7.60	8.08	0.27	0.38
10–20 cm	7.93	7.54	0.30	7.62	7.85	0.54	0.47

† Probability of a greater F by chance between the CO_2 or irrigation treatments and for the CO_2 by irrigation interaction.
‡ FACE = free-air CO_2 enrichment.

net N mineralization (Table 2). In general, net N immobilization occurred during the 0 to 30 d incubation period only (i.e., 0–5 cm depth) suggesting that initially large proportions of available C relative to N led to net N immobilization. Apparently at this period and depth, N was less limiting under the dry treatment since a trend for the wet treatment toward increased net N immobilization was observed. After 30 d, net N mineralization occurred at the 0 to 5 cm depth, suggesting N content was less of a limiting factor in residue decomposition.

During both the 0 to 30 and 30 to 60 d incubation periods, net N mineralization was significantly decreased in the wet treatment at the 5 to 10 cm depth. For the total incubation period, N mineralization decreased under wet conditions at the 0 to 5 and 5 to 10 cm depths; a similar trend was noted at the 10 to 20 cm depth ($P = 0.19$). In contrast, the FACE soils exhibited no significant change in net N mineralization despite higher organic N content at the 5 to 10 and 10 to 20 cm depths.

Soil Respiration

Soil respiration (i.e., soil organic C mineralization) patterns during the experiment are shown in Table 3. The wet treatment during the 0 to 30 d period had a significantly lower level of soil respiration at the surface with a similar trend observed for the total incubation period. Over the total incubation period at the 5 to 10 cm depth, soil respiration was lower under wet conditions, while a trend toward reduced soil respiration was also observed under FACE. For the 30 to 60 d and total incubation periods, a significant interaction between CO_2 and irrigation level occurred at the 10 to 20 cm depth. In these cases, soil respiration was increased by water stress under ambient CO_2 (e.g., 556 mg kg^{-1} for the total incubation period). Under both water levels at 550 μL L^{-1} (e.g., ca. 242 mg kg^{-1} for the total incubation period) soil respiration was similar to the ambient CO_2/wet treatment (e.g., 244 mg kg^{-1} for the total incubation period).

Soil Carbon Turnover

Carbon turnover patterns during the experiment are shown in Table 4. These data can be interpreted differently in relation to the potential for C storage in wheat agroecosystems as affected by changing atmospheric CO_2 and irrigation. The wet treatment during the 30 to 60 d incubation period had a significant decrease in C turnover at the 10 to 20 cm depth. For the total incubation period at the 5 to 10 and 10 to 20 cm depth, C turnover decreased under wet conditions. Generally, the 0 to 5 cm depth followed the same trend, but was

Table 2. Soil N mineralization (mg kg^{-1}) as affected by atmospheric CO_2 level and irrigation treatment. Main effect treatment means are shown.

	Irrigation			CO_2 Level			CO_2 × Irrigation
Depth	Dry	Wet	$P > F$†	Ambient	FACE‡	$P > F$	$P > F$
				0–30 d			
0–5 cm	−1.05	−8.97	0.02	−5.72	−4.30	0.49	0.86
5–10 cm	6.16	3.77	0.10	5.35	4.58	0.59	0.37
10–20 cm	2.26	1.73	0.41	2.16	1.83	0.80	0.22
				30–60 d			
0–5 cm	11.27	11.02	0.95	13.25	9.05	0.15	0.41
5–10 cm	8.70	4.46	0.02	5.53	7.63	0.32	0.55
10–20 cm	4.38	3.55	0.27	4.25	3.69	0.68	0.26
				Total, 0–60 d			
0–5 cm	10.22	2.06	0.05	7.52	4.75	0.31	0.26
5–10 cm	14.86	8.23	0.02	10.87	12.21	0.64	0.89
10–20 cm	6.64	5.28	0.19	6.41	5.51	0.71	0.97

† Probability of a greater F by chance between the CO_2 or irrigation treatments and for the CO_2 by irrigation interaction.
‡ FACE = free-air CO_2 enrichment.

Table 3. Soil C mineralization (mg kg^{-1}) as affected by atmospheric CO_2 level and irrigation treatment. Main effect treatment means are shown.

	Irrigation			CO_2 Level			CO_2 × Irrigation
Depth	Dry	Wet	$P > F$†	Ambient	FACE‡	$P > F$	$P > F$
				0–30 d			
0–5 cm	489.1	307.5	0.02	383.4	413.3	0.72	0.97
5–10 cm	363.1	269.0	0.45	351.8	280.4	0.54	0.22
10–20 cm	187.0	201.6	0.40	211.0	177.6	0.52	0.25
				30–60 d			
0–5 cm	93.4	133.9	0.49	80.6	146.6	0.41	0.40
5–10 cm	130.1	89.0	0.75	129.8	89.4	0.72	0.38
10–20 cm	220.6	32.4	0.03	189.4	63.6	0.17	0.05
				Total, 0–60 d			
0–5 cm	582.5	441.4	0.13	464.0	559.9	0.49	0.54
5–10 cm	493.2	358.0	0.01	481.5	369.8	0.18	0.34
10–20 cm	407.6	234.0	0.03	400.4	241.2	0.03	0.07

† Probability of a greater F by chance between the CO_2 or irrigation treatments and for the CO_2 by irrigation interaction.
‡ FACE = free-air CO_2 enrichment.

only significant during the first 30 d of incubation. Soil respiration was lower under FACE compared to ambient CO_2 at the 5 to 10 and 10 to 20 cm depths for the total incubation period.

These results suggest a potential for soil C storage in FACE soils since soil C mineralization and turnover patterns were found to be essentially the same (i.e., 0–5 cm depth) or decreased (i.e., 5–10 and 10–20 cm depth) relative to ambient CO_2 conditions. For the 30 to 60 d and total incubation periods, a significant interaction between CO_2 and irrigation level occurred at the 10 to 20 cm depth increment. In these cases, C turnover was increased by water stress under ambient CO_2 (e.g., 106 g kg^{-1} for the total incubation period). Under both water levels in the FACE treatment, C turnover (e.g., ca. 42 g kg^{-1} for the total incubation period) was similar to the ambient CO_2/wet treatment (e.g., 37 g kg^{-1} for the total incubation period), suggesting that more C storage is likely under elevated CO_2 regardless of water treatment.

DISCUSSION

The decomposition of crop residue inputs to the soil depends on several abiotic (e.g., soil moisture and soil temperature) and biotic factors (e.g., plant age, lignin content, residue C/N ratio) (Ghidey and Alberts, 1993; Parr and Papendick, 1978). Collectively, these factors influence the rate and extent of organic C turnover, thereby controlling C storage patterns in terrestrial ecosystems (Van Veen et al., 1991). In the present laboratory incubation study, soil temperature and soil moisture were held constant to evaluate soil C and N dynamics as related to the inherent characteristics of crop residue inputs to the soil after 2 yr of wheat production under FACE with differential irrigation treatments.

With wheat, increased biomass inputs due to either well-watered conditions or elevated atmospheric CO_2 (Pinter et al., 1993; 1994) reduced microbial respiration during a 60 d incubation period. Since the net N mineralization data indicates that N cycling in a wheat production system may influence soil C storage under optimal soil moisture, efforts to predict soil C storage need to consider N cycling dynamics concurrently. Results from the present study indicate that N limitations (i.e., lower soil N mineralization) decreased microbial activity (i.e., C mineralization) in the wet treatment which resulted in reduced C turnover. This pattern was clearly evident at the 5 to 10 and 10 to 20 cm depths. This was most likely because the supply of N was changed in proportion to the amount of N needed for the amount of C supplied. On the other hand at the 5 to 10 and 10 to 20 cm depths, FACE reduced soil respiration and C turnover, even though net N mineralization was similar.

Table 4. Soil C turnover (g kg^{-1}) as affected by atmospheric CO_2 level and irrigation treatment. Main effect treatment means are shown.

	Irrigation			CO_2 Level			CO_2 × Irrigation
Depth	Dry	Wet	$P > F$†	Ambient	FACE‡	$P > F$	$P > F$
				0–30 d			
0–5 cm	48.3	33.3	0.04	42.2	39.4	0.69	0.55
5–10 cm	56.0	39.4	0.43	54.3	41.0	0.46	0.27
10–20 cm	34.6	37.2	0.54	40.8	31.0	0.34	0.23
				30–60 d			
0–5 cm	9.9	14.7	0.47	10.4	14.1	0.62	0.52
5–10 cm	18.7	12.6	0.77	20.3	11.0	0.58	0.37
10–20 cm	41.6	4.7	0.03	35.6	10.8	0.20	0.05
				Total, 0–60 d			
0–5 cm	58.1	47.9	0.30	52.6	53.5	0.94	0.95
5–10 cm	74.6	51.9	0.02	74.6	52.0	0.09	0.57
10–20 cm	76.2	41.9	0.04	76.4	41.7	0.03	0.10

† Probability of a greater F by chance between the CO_2 or irrigation treatments and for the CO_2 by irrigation interaction.
‡ FACE = free-air CO_2 enrichment.

It is important to note that changes in soil C storage in terrestrial systems based on N availability or C/N ratios alone (Bazzaz, 1990) may not explain all of the differences observed, especially in the context of net N and C mineralization and C turnover patterns found under FACE conditions at the lower soil depths. For example, FACE tended to reduce soil respiration and C turnover at the 5 to 10 and 10 to 20 cm depths, despite higher soil organic N content relative to ambient CO_2. Furthermore, soil respiration and C turnover at the 10 to 20 cm depth were highest in the dry treatment under ambient CO_2 conditions. However, values from both irrigation treatments under FACE were similar to the ambient CO_2/wet treatment combination, suggesting that more C storage may occur under elevated CO_2 for both irrigated and nonirrigated farm systems. These results indicate that factors other than N may have limited microbial activity in the FACE soil.

Although fundamental changes in plant structure/composition (inclusive of tissue C/N ratios) due to elevated CO_2 may alter the biodegradability of crop residue, few studies have evaluated this, and even fewer studies have used mature/senesced crop residue produced in the field, or soils that reflect field residue inputs over time. Taylor and Ball (1994) reported that the C/N ratio of young sorghum [*Sorghum bicolor* (L.) Moench.] stem tissue (produced in CO_2-enriched growth chambers) was unaffected by CO_2 level, and soils amended with CO_2-enriched plant material had higher soil respiration, suggesting that this material was more easily degraded. However, their results may not be representative of older residue inputs to the soil after a field-harvesting operation. Senesced sorghum residues (stem, leaves, and roots) produced under CO_2-enriched conditions using open top field chambers were found to have significantly higher C/N ratios relative to ambient grown material (Prior et al., 1997). Studies conducted with a lignocarbohydrate-solubilizing actinomycete (*Streptomyces viridosporus*) found that the actinomycete growth and solubilization of lignocarbohydrate were highest for ambient CO_2-grown wheat (i.e., young stem material collected from a growth chamber study) vs. high CO_2-grown material (Ball, 1991, 1992). These results suggest that altered plant structure (e.g., lignification) caused high CO_2-grown material to be more resistant to microbial degradation, but experimental evidence describing lignification was not presented. Akin et al. (1995) provides some insight on the effects of irrigation treatment and FACE on mature wheat fiber quality of leaves and stems as related to digestibility by rumen microorganisms. Under FACE, mature flag leaves had higher neutral detergent fiber, acid detergent fiber, cellulose, and lower lignin content; however, these changes had no effect on digestibility. The lignin content of mature leaf material was lower under dry irrigation, which also resulted in higher digestibility. Similar findings were noted for mature sudangrass [*Sorghum* × *drummondii* (Streudel)] stem material (Akin et al., 1994). It is not known if degradation of aboveground tissue by rumen microorganisms is analogous to the behavior of soil microorganisms.

In the present study, we are unable to ascertain why the effects of CO_2 and its interaction with irrigation treatment varied by soil depth. Different patterns of soil respiration and C turnover could be related to the mixing of aboveground residue with root material within the soil profile. Our N mineralization data, taken in conjunction with findings reported by Akin et al. (1994, 1995), tend to support the view that soil respiration and C turnover were higher under the dry treatment, suggesting that more available N and lower lignin content allowed for greater microbial activity. Upon considering the effects of FACE on measured variables, however, the explanation is less clear. Reduced whole plant water use by elevated CO_2 for some crop species (Prior et al., 1991; Dugas et al., 1997) suggests that preservation of soil water within the soil profile may lead to greater residue decomposition under field conditions. However, this was probably not a major factor in the present study since there was only a small reduction in seasonal evapotranspiration ($\sim$4%) due to FACE for wheat (Grossman et al., 1995). We suspect that changes in root-derived residue inputs are responsible for the significant CO_2 by irrigation interaction noted at the 10 to 20 cm depth. At this depth, soil respiration and C turnover were increased by water stress under ambient CO_2. These measures under both irrigation levels with FACE were similar to the ambient CO_2/wet treatment. Possible structural changes such as lower lignin content could have occurred under the ambient/dry treatment combination vs. its well-watered counterpart, whereas lignin contents were increased under FACE regardless of irrigation regime, thereby limiting soil respiration and C turnover. An alternative explanation may be related to the hypothesis of Goudriaan and de Ruiter (1983). They suggested that increased inputs of soluble, easily decomposed C material produced under CO_2-enriched atmospheric conditions would be the preferred substrate for soil microbes. The end result would be reduced decomposition of plant residue and native soil organic matter and a subsequent accumulation of soil organic matter. Experimental evidence of Lekkerkerk et al. (1990) support this view. In their growth chamber study, CO_2 enrichment of wheat resulted in higher inputs of easily decomposable root-derived C material. Microbial preference for residue produced under elevated CO_2 resulted in a net increase in soil organic matter under high CO_2. Under field conditions, both changes in wheat root structural characteristics and inputs of easily decomposable C compounds may occur under FACE.

In a study similar to ours, an evaluation of soils after 3 yr of cotton residue inputs as affected by FACE indicated that more C storage would occur under wet conditions, whereas C storage under dry conditions was less likely (Wood et al., 1994). Collectively, results from their study and those reported here suggest that the biodegradability of crop residue may not only be affected by the environment they were produced under but may also be species dependent, thereby accounting for differences in soil C storage. In both studies, data indicated that over the short-term, increased soil organic C storage is likely under elevated atmospheric CO_2. However, fundamental changes in crop structural characteristics induced by high CO_2 and the subsequent impact of these changes on decomposition processes may have been different. The relationship between nutrient cycling and decomposition of plant materials produced in an elevated CO_2 environment may also be different for the two plant species (cotton and wheat). These fundamental changes may affect soil management decisions in a high CO_2 world.

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