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Elevated atmospheric CO_2 effects on biomass production and soil carbon in conventional and conservation cropping systems

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Abstract

Increasing atmospheric CO_2 concentration has led to concerns about potential effects on production agriculture as well as agriculture's role in sequestering C. 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 CO_2 levels (ambient = 375 μL L^{-1} and elevated CO_2 = 683 μL L^{-1}) 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 on soil C and biomass responses over two cropping cycles (4 years) were evaluated. In the conservation system, cover crop residue (clover, sunn hemp, and wheat) was increased by elevated CO_2, but CO_2 effects on weed residue were variable in the conventional system. Elevated CO_2 had a greater effect on increasing soybean residue as compared with sorghum, and grain yield increases were greater for soybean followed by wheat and sorghum. Differences in sorghum and soybean residue production within the different management systems were small and variable. Cumulative residue inputs were increased by elevated CO_2 and conservation management. Greater inputs resulted in a substantial increase in soil C concentration at the 0–5 cm depth increment in the conservation system under CO_2-enriched conditions. Smaller shifts in soil C were noted at greater depths (5–10 and 15–30 cm) because of management or CO_2 level. Results suggest that with conservation management in an elevated CO_2 environment, greater residue amounts could increase soil C storage as well as increase ground cover.

Keywords: carbon dioxide, cover crops, grain crops, no-tillage, residue, soil C sequestration

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Introduction

The global atmosphere is changing as documented by the rise in atmospheric CO_2 concentration (Keeling & Whorf, 1994). The anthropogenic causes of this environmental change (e.g. fuel usage, industrial expansion, and land-use changes) are expected to continue (McCarthy *et al*., 2001). Increasing atmospheric CO_2 concentration may impact production agriculture's role in sequestering C since CO_2 is a primary input to crop growth, and C fixed by the plant enters the soil via plant residues. These systems are significant since the amount of C stored in the soil can be easily altered by management practices (e.g. fertility practices, tillage methods, and cropping systems including cover crops) (Kern & Johnson, 1993; West & Post, 2002).

Recent analyses indicate that agricultural systems can act as terrestrial C sinks (Lal *et al*., 1998). Kimble *et al*. (2002) estimated that the C sequestration potential of

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croplands is $0.32\,t\,C\,ha^{-1}\,yr^{-1}$. Mitchell *et al.* (1998) examined the impact of the Conservation Reserve Program and conservation tillage using the Environmental Policy Integrated Climate (EPIC) model and the National Resources Inventory database and found that agricultural soils would be a sink for C in the central United States. West & Post (2002) found that conversion of conventional tillage to a no-tillage system could potentially sequester $0.57\,t\,C\,ha^{-1}\,yr^{-1}$. Follett (2001) reported that conversion to improved tillage and cropping systems in the US could store $30–105\,Mt\,C\,yr^{-1}$. These estimates clearly indicate that managed agricultural systems could potentially help mitigate the rise in CO_2 by storing more C in the soil.

Elevated atmospheric CO_2 has been shown to increase biomass production (Amthor, 1995). The effect of elevated CO_2 on the amount of crop residue can influence soil C dynamics and may increase soil C storage in agroecosystems (Rogers *et al.*, 1999; Torbert *et al.*, 2000). There is, however, a lack of information on how elevated CO_2 will interact with management practices, especially those used in conservation systems. Such information is needed to accurately predict shifts in biomass productivity that will impact soil C storage patterns under different residue management schemes. The capability of soil to act as a sink for C storage in CO_2-enriched agroecosystems is a highly relevant issue since the potential for C storage in agricultural soils is of special interest in the current context of climate change.

In this study, crops were grown in a large outdoor soil bin under two different management practices (conventional tillage and conservation tillage) and atmospheric CO_2 environments (ambient and elevated CO_2) employing the open-top chamber (OTC) atmospheric exposure system as described by Rogers *et al.* (1983a). This exposure system has been in use for many years and since their feasibility was first demonstrated for field exposure of plants to elevated CO_2 (Rogers *et al.*, 1983b), these systems have been successfully employed worldwide (Allen *et al.*, 1992). Much of the OTC work has dealt with individual plant responses (e.g. growth, yield, and physiology); however, they have also been used successfully to examine more complex, ecosystem level responses (e.g. Drake *et al.*, 1989; Curtis *et al.*, 1990; Drake, 1992; Owensby, 1993; Owensby *et al.*, 1993, 1994; Rice *et al.*, 1994; Thompson & Drake, 1994; Dilustro *et al.*, 2001, 2002; Johnson *et al.*, 2001; Wiemken *et al.*, 2001; Williams *et al.*, 2001, 2004; Dukes & Hungate, 2002; Marissink *et al.*, 2002; Mosier *et al.*, 2002; Hymus *et al.*, 2003; Langley *et al.*, 2003; Pataki *et al.*, 2003; Stiling *et al.*, 2003; Morgan *et al.*, 2004; Nelson *et al.*, 2004; Pendall *et al.*, 2004). Our research team has also used OTCs successfully to evaluate both agronomic (Amthor *et al.*, 1994; Reeves *et al.*, 1994; Henning *et al.*, 1996; Torbert *et al.*, 1996, 1998, 2000, 2001, 2004a; Dugas *et al.*, 1997; Prior *et al.*, 1997, 2003, 2004a, b; BassiriRad *et al.*, 1999) and forest systems (Pritchard *et al.*, 2001; Davis *et al.*, 2002; Torbert *et al.*, 2004b). While OTCs may impact micrometeorology (e.g. temperature and relative humidity), recent evidence suggests this has little influence on relative plant response to CO_2. Kimball *et al.* (1997) observed, 'OTC's remain a workable alternative in some experiments that appear technically difficult or too expensive with free-air CO_2 enrichment (FACE)'. Further, recent examinations of exposure methodologies have shown similar results for OTC and FACE systems. Amthor (2001), in a review of studies conducted using wheat, found high variability in yield among differing exposure systems; however, results with OTCs and FACE were quite similar. Similarly, Kimball *et al.* (2002) stated, 'Comparison of the FACE results with those from earlier chamber-based results were consistent, which gives confidence that conclusions drawn from both types of data are accurate'. The FACE approach was not feasible in our study given the physical limitations of the soil bins, thus, the OTC exposure system was used to address questions of agroecosystem level responses to elevated CO_2.

The current study is the first known long-term experiment investigating the interaction of tillage and CO_2 level. The objective was to investigate the effects of increased CO_2 level on biomass production and soil C storage patterns for conventional and conservation tillage management systems.

Materials and methods

The outdoor soil bin facility, located at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL (32.6°N, 85.5°W), has several bins ($7\,m \times 76\,m \times 2\,m$ deep) with representative soil types common to the southern USA (Batchelor, 1984). Each bin was filled with soil supported on a tile and gravel drainage basin in an experimentally constructed soil profile of field proportions; perched water tables were not a problem in this system. The soil bin facility was constructed in the mid-1930s and since the soil bins had been primarily used for the development and testing of new agricultural machinery, they were kept mechanically fallow throughout most of their history; this fact has allowed for monitoring of soil carbon from a very low, stable baseline. Further, the uniformity of these bins provide for a much more homogeneous soil, which leads to greater consistency in growth patterns, than is typically found in the field. Cropping systems study plots were established in the fall of 1997 along the length of one outdoor soil bin filled with a Decatur silt loam soil (clayey, kaolinitic, thermic Rhodic Paleudults). On this soil bin, crops were grown from seed to maturity in OTCs (Rogers *et al*., 1983a) under ambient and elevated atmospheric CO_2 concentrations in two different crop management systems (conventional and conservation tillage).

The OTCs were constructed of a structural aluminum frame (3 m in diameter by 2.4 m in height) covered with a PVC film panel (0.2 mm thickness) similar to those described in detail by Rogers *et al*. (1983a). Carbon dioxide was supplied from a 12.7 Mg liquid CO_2 receiver through a high volume dispensing manifold and the atmospheric CO_2 concentration was elevated by continuous injection of CO_2 into plenum boxes. Air was introduced into each chamber through the bottom half of each chamber cover which was double-walled; the inside wall was perforated with 2.5 cm diameter holes to serve as ducts to distribute air uniformly into the chamber. Three chamber volumes were exchanged every minute. Carbon dioxide concentrations were continually monitored (24 h day^{-1}) using a time-shared manifold with samples drawn through solenoids to an infrared CO_2 analyzer (Model 6252, LI-COR Inc., Lincoln, NE, USA). Values were continuously recorded every 15–30 min for each chamber, depending upon whether or not an additional CO_2 study was on line. The mean daytime CO_2 concentrations were 375.39 ± 0.07 (SE) ($n = 109\,562$; ambient CO_2 treatment) and $683.27 \pm 0.23\,\mu L\,L^{-1}$ (SE) ($n = 109\,591$; elevated CO_2 treatment). The target concentration for the elevated CO_2 treatment was $720\,\mu L\,L^{-1}$. Overall, we were within 20% of the target value 90% of the time. The only down time for CO_2 exposure was associated with tillage and planting operations as described below. It is important to note that chambers used in the current study were constructed without a frustum attached to top of the structural frame to minimize disturbance of rainfall distribution patterns within plots. Further, plot locations were permanently delineated using an anchored structural aluminum ring (3 m in diameter) as a precaution to prevent lateral surface flow of water into or out of plots.

This report covers 4 years (two rotation cycles) in a CO_2 study comparing two crop management systems (conventional and conservation tillage). In the conventional system, grain sorghum (*Sorghum bicolor* (L.) Moench. 'Pioneer 8282') and soybean (*Glycine max* (L.) Merr. 'Asgrow 6101') were rotated each year with spring tillage after winter fallow. To simulate spring tillage operations in this system the following procedures were: (1) a pitch fork was inserted ($\sim$10 cm between insertion points) to a depth of 20–25 cm before heaving the soil to simulate a chisel plowing operation; (2) a large push type PTO tiller (Model 192432, Gardenway Inc., Troy, NY, USA) was operated twice to a soil depth of 15–20 cm to simulate two disking operations; and (3) a small push type garden cultivator (Model 410R, Ryobi Technolgies Inc., Anderson, SC, USA) was operated to a soil depth of 8–10 cm to simulate a field cultivation operation. In the conservation system, grain sorghum and soybean were also rotated, but with three cover crops (crimson clover (*Trifolium incarnatum* L. 'AU Robin'), sunn hemp (*Crotalaria juncea* L. 'Tropic Sunn'), and wheat (*Triticum aestivum* L. 'Pioneer 2684')) which were also rotated; all were grown using 'no-tillage' practices. The conservation system had either cash or cover crops grown throughout the year with no fallow periods (in order of: clover, sorghum, sunn hemp, wheat, and soybean). The sunn hemp cultivar used (i.e. Tropic Sunn), was a joint release of USDA-NRCS and the University of Hawaii Institute of Tropical Agriculture and Human Resources in 1983 and is capable of producing high amounts of biomass and symbiotic nitrogen in a 8–12 weeks frost-free period (NRCS, 1999). Sunn hemp's use as a suitable cover crop has been demonstrated in the tropics (Lales & Mabbayad, 1983; Jeranyama *et al*., 2000) and the southern USA (Mansoer *et al*., 1997; Balkcom & Reeves, 2005). Sunn hemp was used in our system to insure that there was no fallow period prior to wheat planting. The wheat served as cover as well as being harvested for grain. Cover crop seeds were broadcast planted at 56, 112, and 168 kg ha^{-1} for clover, sunn hemp, and wheat, respectively. Clover, soybean, and sunn hemp seeds were inoculated with commercial *Rhizobium* (Nitragin Co., Milwaukee, WI, USA) prior to planting. In both management systems, row crop seeds were sown (20 per meter of row) on 0.38 m row spacings using a hand operated precision garden seeder (Model 1001-B, Earthway, Bristol, IN, USA). However, in the conservation system, a grass edger (Model LE389, Husqvarna, Lawrenceburg, TN, USA) was used to make the seed furrows by cutting through the residue mat prior to using the precision seeder; the furrows were manually closed by hand. Extension recommendations were used in managing the crops; fertilizer rates were based on standard soil tests guidelines as recommended by the Auburn University Soil Testing Laboratory (Adams *et al*., 1994). To ensure adequate plant establishment and grain production for sorghum and wheat, fertilizer N was broadcast applied in split applications. For grain sorghum, fertilizer N was applied at a rate of 34 kg N ha^{-1} shortly after planting and an additional 101 kg N ha^{-1} was applied 30 days after planting. For wheat, fertilizer N was applied at planting (34 kg N ha^{-1}), 3.5 months after planting (67.4 kg N ha^{-1}), and 4.5 months after planting (34 kg N ha^{-1}). Cover crops and sorghum (regrowth prevention) were terminated with glyphosate (*N*-[phosphonomethyl] glycine) 10 days prior to planting the following crop. All operations described above were also conducted on all nonexperimental areas to insure uniform treatment of areas bordering the study plots.

At final harvest, all plants were removed and total fresh weights recorded. For row crops, the stalks were cut into approximately 15 cm lengths using hedge clippers. A subsample of the nonyield material (residue) was taken and its fresh weight recorded; the subsample was dried (55 °C) and total residue was determined by calculation using the fresh weight to dry weight ratio for each plot. The remaining residue material was returned to each study plot and uniformly spread over the plots. For grain crops (sorghum, soybean, and wheat), fresh weights and moisture of threshed grain (Almaco Thresher, Model SVPT, Allan Machine Co., Nevada, IA, USA) were determined; total yields were determined following correction for moisture (Model SL95 Moisture Meter, The Steinlite Corp., Atchison, KS, USA). After threshing, soybean pod hulls and chaff (sorghum and wheat) were added back to the appropriate study plots. In the conventional system (following the fallow period), aboveground weed dry weight was measured as described above and residue was returned to plots prior to spring tillage. It is important to note, that all harvest operations described above were conducted on all nonexperimental areas to insure uniform treatment of areas bordering the study plots.

Soil samples were collected at the end of the second cropping cycle (fourth year) using procedures as described by Prior & Rogers (1992). Cores (3.8 cm diameter) were partitioned into 0–5, 5–10, 10–15, and 15–30 depth increments, sieved (2 mm), and oven dried (55 °C). Subsamples were ground to pass a 0.15 mm sieve and analyzed for total C and total N on a LECO CN 2000 analyzer (LECO Corp., Saint Joseph, MI, USA).

The experiment was conducted using a split-plot design with three replicate blocks. Whole-plot treatments (cropping system) were randomly assigned to half of each block. Split-plot treatments (CO_2 levels) were randomly assigned to two chambers (3 m diameter) within each whole plot. There were a total of 12 chamber plot locations where six of these were ambient CO_2 treatments (three for conventional tillage and three for conservation tillage) and the other six were elevated CO_2 treatments (three for conventional tillage and three for conservation tillage). Statistical analyses of data were performed using the Mixed procedure of the Statistical Analysis System (Littell *et al*., 1996). A significance level of $P<0.10$ was established *a priori*.

Results

As expected, positive biomass responses to CO_2 enrichment were often noted in the first cropping cycle (Fig. 1; Table 1). This cycle began with a evaluation of clover (conservation system) and weed (conventional system) production prior to sorghum planting. A significant $CO_2 \times$ management interaction was noted; elevated CO_2 increased clover residue production by 23%, but had no detectable impact on the weeds. The following sorghum crop was unaffected by management; however, the main effect of CO_2 was significant and residue production was increased by ~14%. Sorghum grain yield was not affected by CO_2 level, but was slightly increased (6%) because of conservation management. The following legume cover crop, sunn hemp, was used to fill a 2-month gap which would have been fallow until wheat planting. Elevated CO_2 resulted in a 32% increase in sunn hemp residue in the conservation system, but there was no weed production in the conventional system because of previous herbicide application. At the next sampling, significant main effects of CO_2 and management indicated that elevated CO_2 increased residue production and that the conservation system produced more residue (wheat) compared with the conventional system (weeds). Wheat grain yield was increased (32%) by elevated

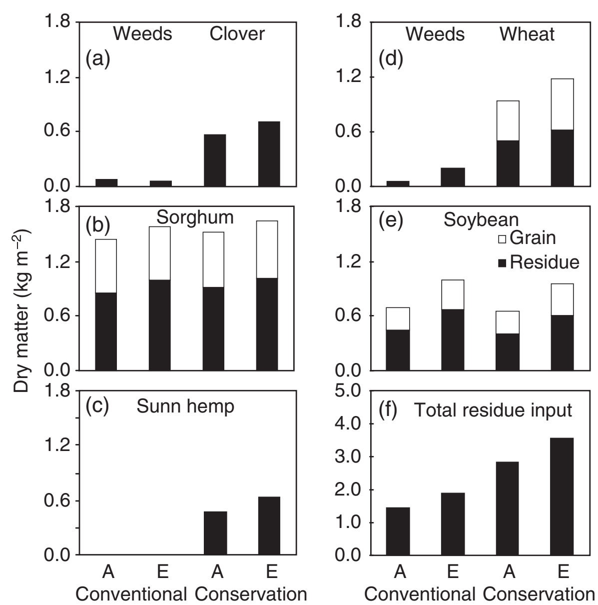

Fig. 1 Biomass production (residue and/or grain) for weeds/clover (a), sorghum (b), sunn hemp (c), weeds/wheat (d), soybean (e), and total residue inputs (f) under ambient (A) and elevated (E) atmospheric CO_2 conditions and two management systems (conventional and conservation) for the first 2-year cropping cycle are shown.

Table 1 Probabilities of CO_2 and management treatment effects on biomass production for weed/clover, sorghum, sunn hemp, weed/wheat, and soybean encompassing the first 2-year cropping cycle

Effect	Weed/clover residue	Sorghum residue	Sorghum grain	Sunn hemp residue	Weed/wheat residue	Wheat grain	Soybean residue	Soybean grain	Total residue
CO_2	0.030	0.005	0.423	0.015	0.049	0.015	<0.0001	<0.0001	<0.0001
System	<0.0001	0.193	0.008	–	0.0001	–	0.006	0.032	<0.0001
System × CO_2	0.010	0.730	0.464	–	0.875	–	0.959	0.806	0.082

Values for cumulative or total residue production for the whole 2-year cropping cycle are included.

CO_2. For soybean, significant main effects of CO_2 and management were also noted. Elevated CO_2 increased soybean residue (49%) and grain production (40%), but conservation management only resulted in a small increase in residue (4%) and grain (6%).

In the second cropping cycle (Fig. 2; Table 2), a significant CO_2 × management interaction was also noted. Elevated CO_2 increased production of clover residue by 22%, but had no impact on weeds. For sorghum, the main effects of CO_2 and management were significant for residue and grain production. Elevated CO_2 increased sorghum residue (24%) and grain (22%), while conservation management resulted in ~13% increase in these variables. Elevated CO_2 resulted in a 61% increase in sunn hemp residue in the conservation system, but there was no weed production in the conventional system because of previous herbicide application. As observed in the first cycle for wheat, significant main effects of CO_2 and management indicated that elevated CO_2 increased residue production and that the conservation system produced more residue (wheat) compared with the conventional system (weeds). For soybean, significant main effects of CO_2 and management were noted for residue production. Elevated CO_2 increased soybean residue by 49%. Conservation management resulted in a small (9%) decrease in residue. For soybean yield, only the main effect of CO_2 was significant; elevated CO_2 increased yield by 52%.

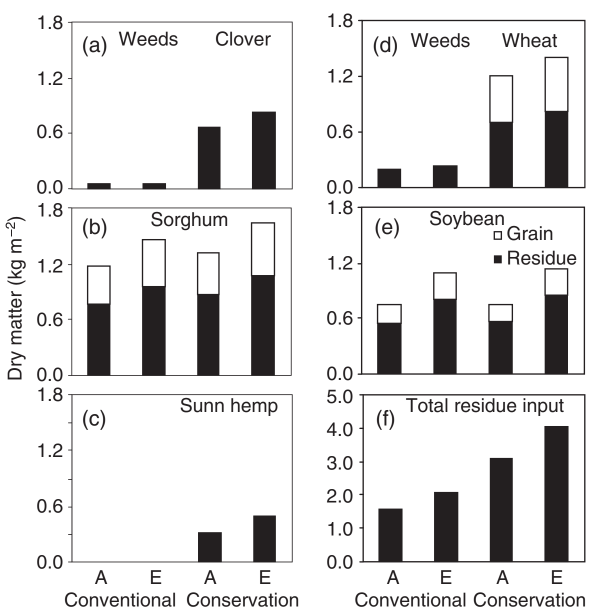

Fig. 2 Biomass production (residue and/or grain) for weeds/clover (a), sorghum (b), sunn hemp (c), weeds/wheat (d), soybean (e), and total residue inputs (f) under ambient (A) and elevated (E) atmospheric CO_2 conditions and two management systems (conventional and conservation) for the second 2-year cropping cycle are shown.

Cumulative nonyield residue inputs to the soil were increased by elevated CO_2 and the use of conservation management (Figs 1F and 2F; Tables 1 and 2). Across both cropping cycles, CO_2 level increased cumulative residue production by ~30% regardless of management practice. Use of conservation practices led to an increase in cumulative residue production of ~90% (both 2-year cycles).

Increases in cumulative inputs resulted in changes in soil C and N concentration (Fig. 3); changes in soil N concentration followed a similar pattern as observed with soil C concentration over the depth increments evaluated. The most notable difference attributable to management practice was observed at the top depth increment (0–5 cm). Clearly, increased inputs combined with lack of tillage (conservation management) resulted in a higher soil C concentration. For the surface increment (0–5 cm), significant main effects of CO_2 ($P = 0.008$) and management ($P = 0.002$) were noted in addition to a significant CO_2 × management interaction ($P = 0.036$). In this case, elevated CO_2 resulted in a dramatic increase in soil C concentration (44%) compared with ambient CO_2 in the conservation treatment. The effect of elevated CO_2 was also higher in the conventional treatment, but this was not statistically significant. The main effects of CO_2 and management were significant for other depth increments, but these

Table 2 Probabilities of CO_2 and management treatment effects on biomass production for weed/clover, sorghum, sunn hemp, weed/wheat, and soybean encompassing the second 2-year cropping cycle

Effect	Weed/clover residue	Sorghum residue	Sorghum grain	Sunn hemp residue	Weed/wheat residue	Wheat grain	Soybean residue	Soybean grain	Total residue
CO_2	0.007	<0.0001	0.0002	0.011	0.011	0.016	<0.0001	0.001	<0.0001
System	<0.0001	0.001	0.004	–	<0.0001	–	0.095	0.528	<0.0001
System × CO_2	0.020	0.552	0.347	–	0.259	–	0.250	0.861	0.001

Values for cumulative or total residue production for the whole 2-year cropping cycle are included.

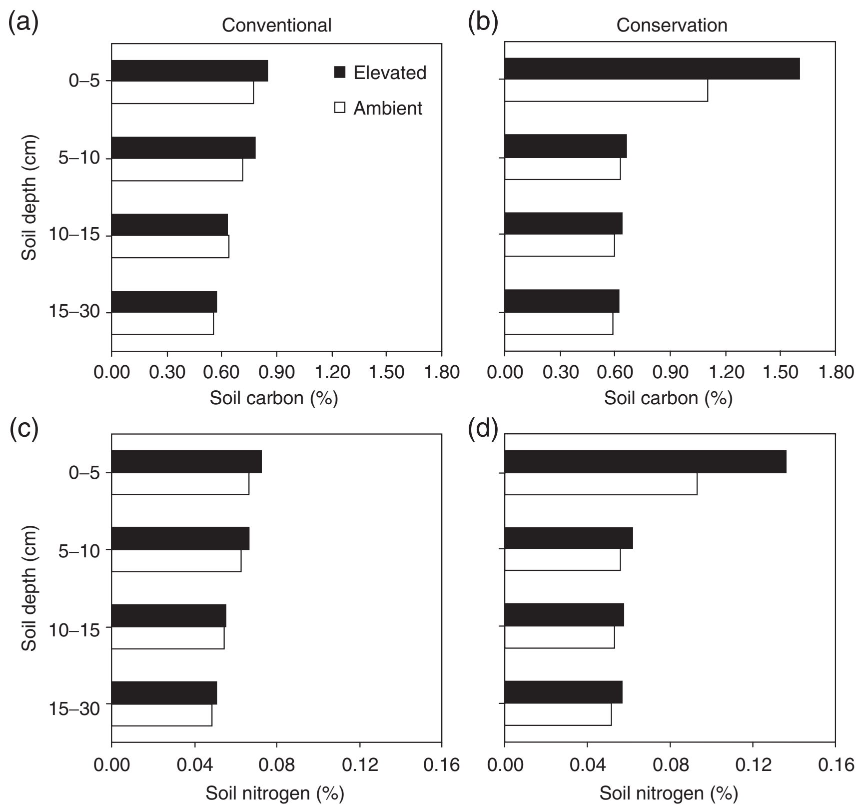

Fig. 3 Soil carbon (a, b) and nitrogen (c, d) concentration at various depth increments as affected by atmospheric CO_2 level (ambient and elevated) and management system (conventional (a, c) and conservation (b, d)) after two complete cropping cycles (4 years) are shown.

differences were not as dramatic as observed at the top depth. CO_2-induced increases in soil carbon also occurred at the 5–10 cm depth ($P = 0.086$) with a similar trend noted at the 15–30 cm depth ($P = 0.142$). Soil C was decreased at the 5–10 cm depth under conservation management ($P = 0.005$). Conservation management increased soil C concentration at the 15–30 cm depth ($P = 0.027$). The main effects of CO_2 ($P = 0.320$) or management ($P = 0.376$) or the interaction ($P = 0.279$) were not significantly different at the 10–15 cm depth increment.

Changes in soil N concentration followed a similar pattern as observed with soil C concentration over the depth increments evaluated. Again, the top depth increment (0–5 cm) clearly shows an increase in soil N, reflecting the impact of management practice. At this depth, significant main effects of CO_2 ($P = 0.003$) and management ($P < 0.0001$) were found in addition to a significant CO_2 × management interaction ($P = 0.013$); a 46% increase in soil N occurred under elevated CO_2 conditions compared with ambient CO_2 in the conservation treatment. The effect of elevated CO_2 was also higher in the conventional treatment, but this was not statistically significant. The main effects of CO_2 and management were significant for other depth increments. CO_2-induced increases in soil N occurred at the 5–10 cm ($P = 0.016$) and 15–30 cm ($P = 0.038$) depth increments. Soil N was decreased at the 5–10 cm depth with conservation management ($P = 0.007$). Conservation management increased soil N concentration at the 15–30 cm depth ($P = 0.024$). The main effects of CO_2 ($P = 0.113$) or management ($P = 0.896$) or the interaction ($P = 0.267$) were not significantly different at the 10–15 cm depth increment.

Discussion

Aboveground biomass production was often stimulated by elevated atmospheric CO_2. Increased amounts of cover crop residue were produced under CO_2 enrichment in the conservation system. As expected, the legume cover crops (clover and sunn hemp) were more responsive to elevated CO_2 conditions than wheat. Within the conventional tillage system, the variable response of weeds to CO_2 indicates that further work is required to clarify management implications.

For the summer row crops, rising CO_2 levels can be expected to increase soybean residue production more than that of sorghum. These results were not surprising because of difference in how these crops utilize CO_2 during photosynthesis. Crops with a C_3 photosynthetic pathway (soybean) often exhibit a greater CO_2 response compared with C_4 crops (sorghum) since the CO_2-concentrating mechanism in C_4 species limits the growth response (Amthor, 1995). Differences in grain yield were also noted during the study. Our results indicate that grain yield will likely be increased (because of elevated CO_2) for soybean followed by wheat and sorghum. In general, the relative response of these major crops to changing CO_2 level supports field findings reported by others (Kimball *et al*., 2002; Prior *et al*., 2003). We also noted that differences in residue production (for both sorghum and soybean) between management systems (conventional vs. conservation) may not be appreciable under elevated CO_2.

Cumulative residue production is likely to be increased by CO_2 enrichment and conservation management. Larger residue inputs were associated with increased soil C and vertical stratification of C within the soil profile. Changes in soil N will likely follow similar stratification patterns as observed with soil C over depths evaluated. This was particularly apparent in the conservation tillage system. Stratification of C within soil profiles has been commonly reported for highly managed agricultural systems such as pastures and no-tillage/conservation row crop systems under ambient CO_2 concentrations and in native systems such as grasslands/rangelands and forest systems (Potter *et al*., 1998, 1999; Torbert *et al*., 2003). This pattern arises from a long-term history of undisturbed soil profiles coupled with surface litter. Results suggest that in a future elevated CO_2 world, agroecosystems could potentially store more C in the soil. However, the potential to sequester C appears to be greater for conservation systems than for conventional systems. Future plans for this work are to continue both CO_2 and management treatments for a total of 10 years (i.e. total of five cropping cycles) to more fully evaluate the long-term nature of C storage in CO_2-enriched agroecosystems.

Our results also suggest that with conservation management in an elevated CO_2 environment there will be larger amounts of crop residue and consequently more ground cover. Accumulation of additional surface litter may improve water infiltration (and storage) and help ameliorate water quality problems by reducing runoff and soil erosion. Future efforts will assess CO_2 effects on other belowground processes in these management systems; root and rhizosphere dynamics, distribution of nutrients in the soil profile, soil water-holding capacity, and soil physical properties will be considered.

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