Elevated Atmospheric CO_2 Effects on Residue Decomposition of Different Soybean Varieties

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ABSTRACT

Elevated atmospheric CO_2 can result in larger plants returning greater amounts of residues to the soil. However, the effects of elevated CO_2 on carbon (C) and nitrogen (N) cycling for different soybean varieties has not been examined. Aboveground residue of eight soybean varieties (*Glycine max* [L.] Merr.) was collected from a field study where crops had been grown under two different atmospheric CO_2 levels [370 ppm (ambient) and 550 ppm (free-air carbon dioxide enrichment) (FACE)]. Senesced residue material was used in a 60 day laboratory incubation study to evaluate potential C and N mineralization. Residue N concentration was usually increased by FACE, but residue C concentration was not altered. Varietal differences were observed with the oldest variety having the lowest residue N concentration and highest residue C:N ratio. Residue C:N ratio was lower under FACE which could be attributed to increased N fixation. Mineralized N was usually increased by FACE, except for a non-nodulating variety, suggesting that increased N fixation impacted residue decomposition. Mineralized N was lowest in the oldest variety illustrating the influence of high residue C:N ratio. Across varieties, mineralized C was increased slightly by FACE, however, differences in varieties suggest that the impact of elevated CO_2 on C mineralization could be influenced by soybean variety selection.

INTRODUCTION

The unprecedented discharge of CO_2 into the atmosphere (mainly from fossil fuel burning and land use change associated with industrial and/or population expansion) has led to a significant rise in its global concentration. Since CO_2 is a primary input for crop growth, questions concerning its influence on highly managed agricultural systems have arisen.

Numerous past studies have demonstrated that elevated CO_2 often enhances biomass production (Kimball et al., 2002). In addition, shifts in tissue quality or nutrient content have been noted with crops grown under elevated CO_2 conditions. For example, shifts in tissue N concentration and C:N ratio due to high CO_2 may be important factors influencing rates of decomposition and plant N availability in terrestrial ecosystems (Torbert et al., 2000).

More work is needed to accurately determine whether differences in crop residue, due to elevated CO_2, will influence soil carbon storage. Our objective was to investigate the effects of elevated CO_2 on carbon and nitrogen cycling for residues from eight soybean varieties in a 60 day laboratory incubation study.

MATERIALS AND METHODS

Plant material for this incubation study was collected from a elevated atmospheric CO_2 study conducted using a free-air carbon dioxide enrichment (FACE) exposure system. The CO_2 regimes were ambient (370 ppm) and free-air carbon dioxide enrichment (FACE; 550 ppm). Eight soybean varieties were evaluated (Table 1). The experiment was conducted using a randomized complete block design with four replications.

Soybean varieties were planted on 30-cm row spacing at a density of 20 plants m^{-1}. The soil series at the study site (Crop Sciences Research and Education Center of the University of Illinois at Urbana, IL) is a Drummer silty clay loam (fine-silty, mixed, superactive, mesic Typic Endoaquolls). Final harvest was performed in October 2001 and seeds were separated from residue material (pod hull, leaves, and stems) which would normally remain in the field at harvest. Residue material was dried at 65°C (until weight loss was complete) and ground in a Wiley mill to pass a 0.44-mm screen. A sub-sample of this ground residue material was collected for each variety for analysis in the incubation procedures. Total C and N contents of plant samples were determined using a Fisons NA1500 CN Analyzer (Fisons Instruments Inc., Beverly, MA).

Potential soil C and N cycling were determined using methods of Torbert et al. (2000). Sieved soil samples of Drummer silty clay loam were weighed (25 g dry weight basis) and placed in plastic containers; then deionized water was added to adjust soil water content (soil water content equivalent to -20 kPa at a bulk density of 1.3 Mg m^{-3}). Plant residue was added at a rate of 0.1 g to the soil surface and incorporated throughout the soil. Containers were placed in sealed glass jars with 10 ml of water (humidity control) and a 10 ml vial of 1 M NaOH (CO_2 trap). Jars were incubated in the dark at 25°C and removed after 60 days. 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. Soil inorganic N (NO_3-N and NH_4-N) was extracted with 2 M KCl and measured by standard colorimetric procedures using a Bran Luebbe Autoanalyzer III (Buffalo Grove, IL). Potential N mineralization was the difference between inorganic N contents of samples compared to blanks (soil with no plant residue additions).

Statistical analyses of data were performed using the Mixed procedure of the Statistical Analysis System (SAS, 1996). A significance level of P < 0.10 was established *a priori*.

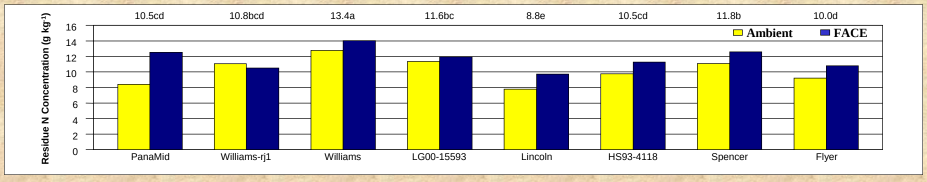

Figure 1. Initial residue N concentration of eight soybean varieties as affected by CO_2 level. N=4.
- ✓ Main effect of CO_2 significant ($p<0.0001$); N increased by FACE in most cases (overall mean of 10.2 g kg^{-1} for Ambient vs. 11.7 g kg^{-1} for FACE)
- ✓ Main effect of variety significant ($p<0.0001$); main effect means shown at top of graph (means with the same letters are not significantly different from each other)
- ✓ No significant interaction noted ($p=0.120$)

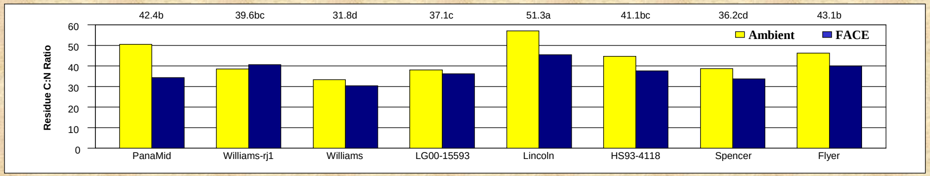

Figure 2. Initial residue C:N ratio of eight soybean varieties as affected by CO_2 level. N=4.
- ✓ Main effect of CO_2 significant ($p<0.0002$); C:N ratio lowered by FACE in most cases (overall mean of 43.4 for Ambient vs. 37.3 for FACE)
- ✓ Main effect of variety significant ($p<0.0001$); main effect means shown at top of graph (means with the same letters are not significantly different from each other)
- ✓ No significant interaction noted ($p=0.104$)

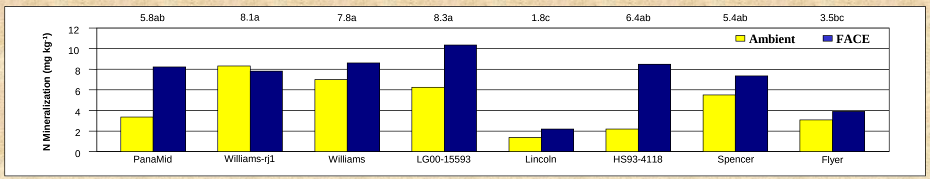

Figure 3. N mineralization of incorporated residues for eight soybean varieties as affected by CO_2 level. N=4.
- ✓ Main effect of CO_2 significant ($p<0.015$); N mineralization increased by FACE in most cases (overall mean of 4.64 for Ambient vs. 7.12 mg kg^{-1} for FACE)
- ✓ Main effect of variety significant ($p<0.017$); main effect means shown at top of graph (means with the same letters are not significantly different from each other)
- ✓ No significant interaction noted ($p=0.661$)

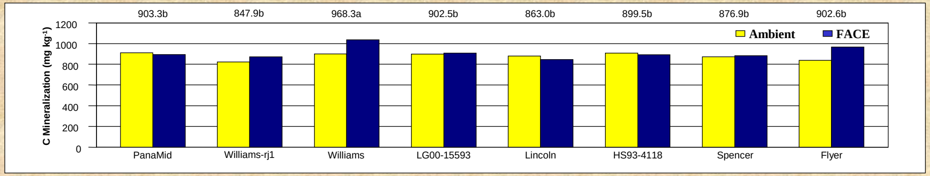

Figure 4. C mineralization of incorporated residues for eight soybean varieties as affected by CO_2 level. N=4.
- ✓ Main effect of CO_2 significant ($p<0.074$); C mineralization slightly increased by FACE (overall mean of 878.7 for Ambient vs. 912.3 mg kg^{-1} for FACE)
- ✓ Main effect of variety significant ($p<0.084$); main effect means shown at top of graph (means with the same letters are not significantly different from each other)
- ✓ No significant interaction noted ($p=0.149$)

Table 1. Eight soybean varieties used in the incubation study.

Variety	General Characteristics
PanaMid	Nodulated; maturity group III
Williams-rj1	Non-nodulated; maturity group III
Williams	Nodulated; maturity group III; seed protein 42%
LG00-15593	Nodulated, maturity group III, seed protein 48%; [Williams (3) x Wisconsin Black]
Lincoln	Nodulated; maturity group III; released 1943; best public cultivar seperated by >50yrs (vs. HS93-4118)
HS93-4118	Nodulated; maturity group IV; released 1998; best public cultivar separated by >50yrs (vs. Lincoln)
Spencer	Nodulated; maturity group IV; released 1998; CO_2 responder
Flyer	Nodulated; maturity group IV; released 1998; CO_2 non-responder

RESULTS AND CONCLUSIONS

- Differences in residue N were noted between varieties with the oldest (Lincoln; see Table 1) having the lowest value (Fig. 1).
- Residue N was usually increased by FACE (Fig. 1), with the exception of the non-nodulating variety (Williams-rj1).
- FACE had no effect on residue C concentration (data not shown).
- Varietal differences in residue C:N ratio were noted with the Lincoln (oldest variety) being the highest (Fig. 2).
- Residue C:N ratio was lower under FACE (Fig. 2) which was likely due to increased N fixation.
- N mineralization was the lowest in the old variety (Lincoln) reflecting the influence of residue quality factors such as high C:N ratio (Fig. 3).
- N mineralization was usually increased by FACE for varieties evaluated (Fig. 3), with the exception of the non-nodulating variety (Williams-rj1) indicating that the stimulation of N fixation will increase N mineralization.
- Differences in C mineralization were noted between varieties with the Williams having the highest value (Fig. 4).
- C mineralization was increased slightly by FACE for varieties evaluated (Fig. 4). However, differences in varieties suggest that the impact of elevated CO_2 on C mineralization could be influenced by soybean variety selection.

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