CHARACTERIZATION OF SOIL GAS EFFLUX PATTERNS ASSOCIATED WITH TILLAGE IMPLEMENTS

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ABSTRACT

Soil disturbance can result in the rapid loss of carbon from soil in the form of carbon dioxide (CO_2). However, soil CO_2 loss characteristic of different farm implements has not been adequately investigated. Our objectives were to compare implement-induced short-term CO_2 loss from soil (using two chamber systems) and to characterize spatial changes in CO_2 flux from zones of soil disturbance caused by these implements. Four-row implements were used on a Norfolk loamy sand (Typic Kandiudults; FAO classification Luxic Ferralsols). The implements tested were two in-row subsoilers (a KMC-Kelly® Ripper and a Brown-Harden Ro-Till®) and a Kinze® planter. Gas flux measurements were made with a large canopy chamber (over the center two rows) for an integrated assessment of equipment-induced soil disturbance; a small soil chamber system was also used to characterize positional effects (i.e., in the row and trafficked and untrafficked row middles) on soil CO_2 efflux. The small chamber system showed that trafficked areas exhibited lower CO_2 efflux relative to in-row and untrafficked row positions. Comparable CO_2 flux patterns were noted between the large canopy and small soil chamber systems (averaged over all positions). Results from this study suggest that both chamber systems could successfully characterize implement-induced flux patterns on loamy sand soils and that consideration should be given to selecting equipment that conserves soil resources.

INTRODUCTION

The rise in atmospheric CO_2 level has received increased attention because potential changes in climate may increase temperature and drought over present agricultural production areas (Wood, 1990). Agriculture may play a critical role in sequestering carbon in soil (Lal et al., 1999), however, there is a need for direct measurements to quantify CO_2 fluxes as impacted by agricultural management practices. Descriptions of short-term CO_2 loss patterns associated with tillage activity have been reported, however, observed responses are dependent on such factors as the type of tillage tool being examined, soil type, season of the year, and regional location (e.g., Prior et al., 2000, 2004; Reicosky and Lindstrom, 1993; Reicosky et al., 1997). Consideration of such factors in conjunction with management decisions that affect tillage intensity are important in characterizing the potential of various cropping systems to store soil carbon.

Detailed information on the effects of the disturbance associated with different types of tillage equipment in terms of CO_2 release is lacking. The objectives of this work were to compare the effect of implement types on short-term soil CO_2 loss using two chamber systems (large and small) and to characterize short-term spatial changes in CO_2 flux from different zones of disturbance caused by these implements.

METHODS AND MATERIALS

This gas flux study using two chamber methods was conducted on a conventional tillage system and occurred concurrently with previously reported work on implement-induced gas fluxes from residue covered soils that used only the large chamber system (Prior et al., 2000). Three commercially available four-row implements (76-cm row spacing) were evaluated on a Norfolk loamy sand that had been in conventional tillage for 10 years at the E.V. Smith Research Center of the Alabama Agricultural Experiment Station in east central Alabama. Since subsoiling a narrow strip over-the-row is a common practice on Coastal Plain soils in the southeast, two in-row subsoilers were evaluated: a KMC-Kelly® Ripper (Kelly Manufacturing, Tifton, GA) and a Brown-Harden Ro-Till® (Brown Manufacturing Corporation, Ozark, AL). Both implements have a rippled coulter in front of the subsoiler shanks and were operated at a depth of 40 cm. The KMC had a 3.2-cm wide straight shank (~40° forward angle; 4.5-cm wide point) and was equipped with paired pneumatic tires to close the subsoil channel (10-cm wide disturbed surface zone). The Ro-Till had a 3.8-cm wide parabolic shank (5-cm wide point), paired fluted coulters and a rolling metal basket to close the subsoil channel (45-cm disturbed surface zone). We also tested a Kinze® planter (Williamsburg, IA) equipped with Martin® row cleaners (Elkton, KY) which uses a double-disk opener to make the seed furrow. The row cleaners consist of metal interlocking toothed wheels set to just clear the soil surface, effectively brushing residue aside (5- to 8-cm wide zone) in front of the seeding openers. A John Deere 4450® tractor (5781 kg, 104 kW) was used for all operations.

There was little rainfall preceding this study thus the soil was very dry. Therefore, 15-mm of irrigation was uniformly applied to study areas (10 m x 10 m) 24 h prior to tillage operations and gas exchange measurements. A dry reference area was also maintained. A total of six 20-cm cores were collected for soil moisture; after wet mass was determined, samples were dried at 105^{o}C for 72 hr. Soil water values for dry reference and irrigated areas were ~37 and 60 g kg^{-1}, respectively.

Equipment-induced soil gas fluxes were measured at midday using two dynamic chamber methods: a large portable canopy chamber (area=2.71 m^2) (Reicosky and Lindstrom, 1993); and a small soil chamber (area=0.0071 m^2) (Prior et al., 1997). The large chamber system was housed on a small forklift that could be easily moved to plot locations. The small chambers system was hand portable. Three sets of gas exchange measurements were made with the large chamber (over the center two rows) for an integrated assessment of equipment-induced soil disturbance on all areas immediately following implement operations as well as on the reference areas. Spatial variation in CO_2 flux was assessed with a small chamber system (LI-COR 6000-09®; LI-COR Inc., Lincoln, NE). Three zones were evaluated: 1) undisturbed zone; 2) in-row disturbance zone (e.g., subsoiling); and 3) tire track zone (three measures per zone). Averaging flux values across all three positions allowed for a direct comparison of small chamber fluxes to those of the large chamber system. Flux readings were also taken in reference areas.

RESULTS AND DISCUSSION

The magnitude of CO_2 fluxes from a disturbed in-row zone, a trafficked interrow zone, and an untrafficked interrow zone were characterized with the small chamber system (Fig. 1). For the Kinze and KMC areas, CO_2 fluxes in the in-row disturbed zones and untrafficked interrow zones were higher relative to trafficked zones, indicating that recompaction from wheel traffic reduced soil CO_2 efflux. However, for the Ro-Till, in-row and untrafficked zone fluxes were lower in magnitude than those observed in the other implement areas. Although these Ro-till observations were unexpected due to greater degree of soil disturbance (vs. the other two implements), results of the small system were supported by findings from the large system (Fig. 2). It is possible that the vigorous soil disturbance from the Ro-Till may have resulted in an immediate release of soil CO_2

which was not detected. Another possible explanation is that the vigorous action of the rolling metal basket (used to close the subsoil channel) may have re-compacted the soil, thereby slowing CO_2 loss to the atmosphere. The Ro-Till implement left narrow undisturbed interrow zones in close proximity to disturbed in-row zones; this may explain the similar flux rates from these zones. Also, CO_2 flux rates in the disturbed in-row and undisturbed untrafficked interrow zones for the Kinze and KMC implements were similar to the reference irrigated area, suggesting that the higher flux rates compared to trafficked interrow zones were due to low soil consolidation and possibly higher microbial activity.

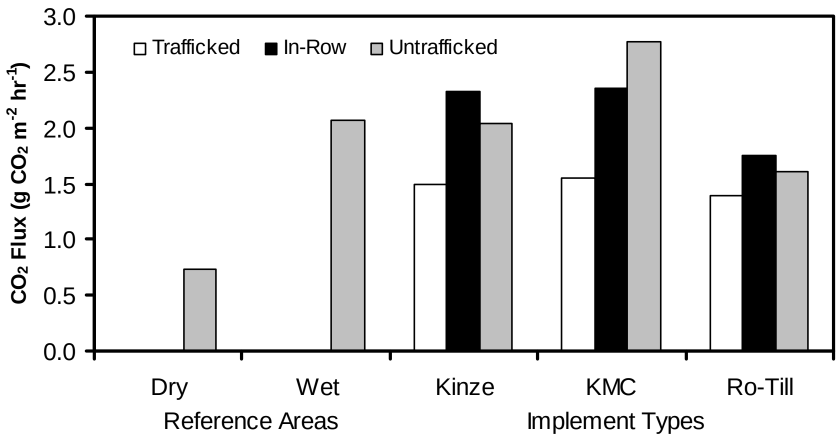

Figure 1. CO_2 fluxes immediately after implement operations using the small chamber system for each position (trafficked, in-row, and untrafficked zones); reference area fluxes also shown.

As noted with the small chamber system, large chamber flux differences between implements did not follow the expected trend with respect to soil disturbance (Fig. 2). Kinze and KMC areas had slightly higher flux rates (vs. Ro-Till) even though the Ro-Till area exhibited a greater degree of soil disturbance. In contrast, use of the large chamber system on residue covered soils (conservation system) found that the Ro-Till exhibited the greatest change in gas fluxes relative to the control plot (Prior et al., 2000).

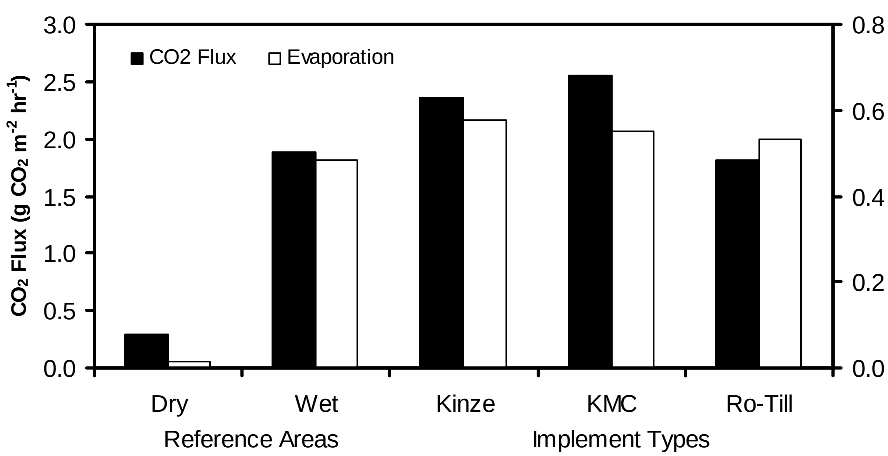

Figure 2. CO_2 and water fluxes immediately after implement operations using the large chamber system; reference area fluxes also shown.

The large system also measured water vapor losses which were similar to CO_2 flux patterns.

Further, with the large system it was clearly noted that irrigation increased both water vapor and CO_2 fluxes; similar CO_2 fluxes were also noted with the small system. Gas losses due to implement use were not substantially different from the irrigated reference area, suggesting that the largest effect on soil gas flux may be related to enhanced microbial activity. These large irrigation-induced fluxes were not seen on residue covered soils (Prior et al., 2000) thereby illustrating the importance of residue cover for enhancement of soil C storage and water availability for crop germination. Runion et al. (2004) suggested that no-till microbial communities are a younger, more viable growing population, while those under conventional tillage are a more mature, static community that can change toward a more active phase of growth as a result of tillage.

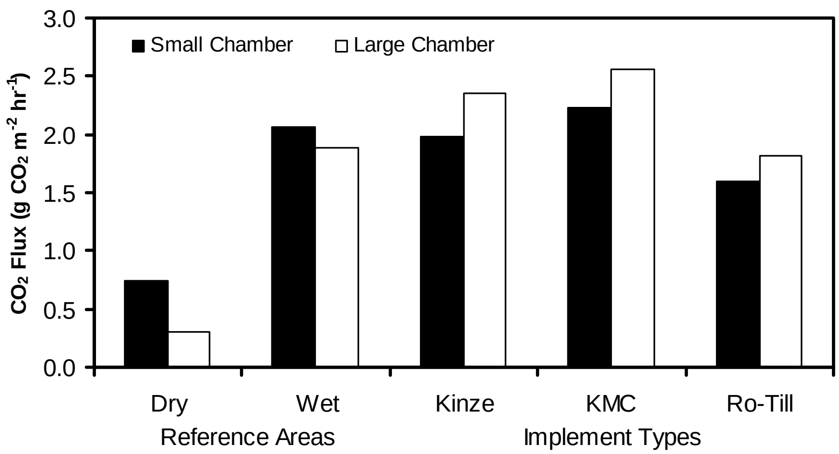

Figure 3. Comparison of CO_2 fluxes between the small and large canopy chamber systems for reference areas and implement types.

Similar temporal CO_2 flux patterns were observed with both the large and small soil chamber systems (Fig. 3). In general, the large chamber system gave slightly higher values which is likely reflective of an integrated assessment of a larger surface area. Although the smaller system assesses a smaller area, it has the advantage of detecting spatial differences. The general agreement between the two systems is in contrast to observations reported by Reicosky et al. (1997) using these systems. This discrepancy may be due to differences in soil type. The presence of soil cracks and air gaps precluded a representative measure of gas flux with the small system in the study on a Pellic Vertisol by Reicosky et al. (1997); these conditions did not exist for the sandier soil in our study.

CONCLUSIONS

This work demonstrated that implement operations can cause immediate loss of C from soil. Similar temporal gas flux patterns were observed with both chamber systems; spatial differences in CO_2 fluxes patterns from different zones following implement use were attributed to soil reconsolidation from tractor wheel compaction. Findings suggest that both systems could successfully characterize flux patterns on loamy sand soils and that consideration should be given to selecting equipment that conserves soil resources.

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