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Short communication

Residue and tillage effects on planting implement-induced short-term CO_2 and water loss from a loamy sand soil in Alabama

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Abstract

Recent research indicates tillage operations result in a rapid physical release of CO_2 and water vapor from soil. However, effects of soil disturbance on gas fluxes during planting operations have not been adequately explored. Our objective was to measure short-term gas loss resulting from the use of different planting preparation implements on long-term residue-covered soil (no-till) on a Norfolk loamy sand (Typic Kandiudults; FAO classification Luxic Ferralsols) in east-central Alabama, USA. A crimson clover (*Trifolium incarnatum* L.) cover crop was killed with herbicide two weeks prior to the study. Due to dry soil conditions, 15 mm of water was applied 24 h prior to study. Gas fluxes were measured with a large canopy chamber (centered over two rows) for an integrated assessment of equipment-induced soil disturbance. Increased losses of CO_2 and water vapor were directly related to increases in soil disturbance. Although these short-term C losses are minor in terms of predicting long-term C turnover in agro-ecosystems, results suggest that selecting planting equipment that maintains surface residue and minimizes soil disturbance could help to conserve soil water needed for successful seedling establishment in these coarse textured soils. Published by Elsevier Science B.V.

Keywords: Loamy sand soil; CO_2 and water loss; Gas fluxes

1. Introduction

The global rise in atmospheric CO_2 concentration is well documented (Keeling and Whorf, 1994). Agro-ecosystems have been viewed as CO_2 sources largely due to the impact of long-term cultivation on reducing soil C content (Houghton et al., 1983). However, recent reviews indicate that management decisions that affect tillage intensity and the amount and placement of residues (e.g., conservation tillage) can increase soil C storage, thereby becoming a viable strategy to help mitigate the rise in atmospheric CO_2 (Reeves, 1997; Lal et al., 1999). Rates of CO_2 flux from tillage operations have recently been studied (e.g., Reicosky and Lindstrom, 1993). However, information on the influence of soil disturbance associated with equipment used during planting operations on CO_2 and water vapor release is lacking. The objective of this work was to determine the effect of implement

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types on short-term soil CO_2 and water vapor losses for a residue-covered soil.

2. Methods and materials

This research was part of a long-term field study (Reeves et al., 1992; Torbert et al., 1996) on a Norfolk loamy sand at the E.V. Smith Research Center of the Alabama Agricultural Experiment Station in east-central Alabama, USA. The management condition selected for study was a no-till area (8*y*) which was covered with a dense residue mat from a winter cover crop of crimson clover that had been killed with herbicide two weeks prior to this study. The limited area available for study was small, thus the study could not be fully replicated. Specifically, areas needed to adjust implements, conduct realistic tillage trials, and for equipment turnaround and access consumed a major part of available space. However, the test area selected was immediately adjacent to a long-term study and the entire field is uniform as shown by past experiments (Reeves et al., 1992), suggesting uniformity within the plots studied. Within this area, four experimental plots ($10 \text{ m} \times 10 \text{ m}$) were established: three were used for implements and one as a control reference plot.

Three commercial four-row implements with 76 cm spacings were used, including two types of in-row subsoilers. Subsoiling a narrow strip over-the-row, called strip-tillage, is a common practice during planting operations on coastal plain soils in the southeastern USA. The two subsoilers were a KMC-Kelly® Ripper (Kelly Manufacturing, Tifton, GA 31793) and a Brown-Harden Ro-Till® (Brown Manufacturing Corporation, Ozark, AL 36360). Both had a rippled coulter in front of subsoiler shanks and were operated at a depth of 40 cm. The KMC had a 3.2 cm wide straight shank ($\sim 40°$ 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 (45 cm disturbed surface zone) to close the subsoil channel. We also tested a Kinze® planter (Williamsburg, IA 52361) equipped with Martin® row cleaners (Elkton, KY 42220) which uses a double-disk opener to make the seed furrow. The row cleaners consist of metal wheels with interlocking teeth set to just clear the soil surface, effectively brushing residue (5–8 cm wide zone) from in front of seeding openers. All operations used a John Deere 4450® tractor (5781 kg, 104 kW).

There was little rainfall preceding this study and the soil was very dry. Therefore, 15 mm of irrigation water was applied to study plots 24 h prior to tillage and gas flux measurements. A handheld coring tube (25 mm diameter and 20 cm long) was used to collect soil samples from adjacent area for estimates of soil water content and total N and C content. Six soil cores were collected and composited 24 h after irrigation for a total of 4 composite samples. After wet mass was determined, samples were oven dried (105°C, 72 h) and dry mass determined. The mean soil water content was 79.7 g kg^{-1}. Subsamples of soil were sieved (2 mm mesh) to remove residue fragments, dried (55°C), ground (1 mm mesh), and analyzed for total N and C content (Fison NA1500 CN Analyzer; Fison Instruments, Beverly, MA). The respective mean N and C values were 0.48 and 7.0 g kg^{-1}.

Equipment-induced soil gas fluxes were measured at midday immediately following implement operations using a large portable canopy chamber (area = 2.71 m^2) (Reicosky and Lindstrom, 1993). Three sets of measurements were made (centered over two rows) for an integrated assessment of equipment-induced gas flux on all areas within 30–60 s following implement operations as well as on the control reference area.

3. Results and discussion

Upon introducing implement operations on residue plots, flux rates increased as the degree of soil disturbance increased (Fig. 1). This is similar to reports by others for tillage operations (Reicosky and Lindstrom, 1993). The Kinze planter created the smallest disturbed surface zone (5–8 cm) and flux values ($0.37 \text{ g } CO_2 \text{ m}^{-2} \text{ h}^{-1}$ and $0.14 \text{ mm } H_2O \text{ h}^{-1}$) were slightly higher than the residue area with no implement operation ($0.29 \text{ g } CO_2 \text{ m}^{-2} \text{ h}^{-1}$ and $0.08 \text{ mm } H_2O \text{ h}^{-1}$). Relative to the same residue control plot, the KMC operation (10 cm disturbed surface zone and subsoil channel) increased fluxes of CO_2 (4*x*) and water vapor (2*x*). Further, the Ro-Till which had the maximum width of soil disturbance (45 cm) and

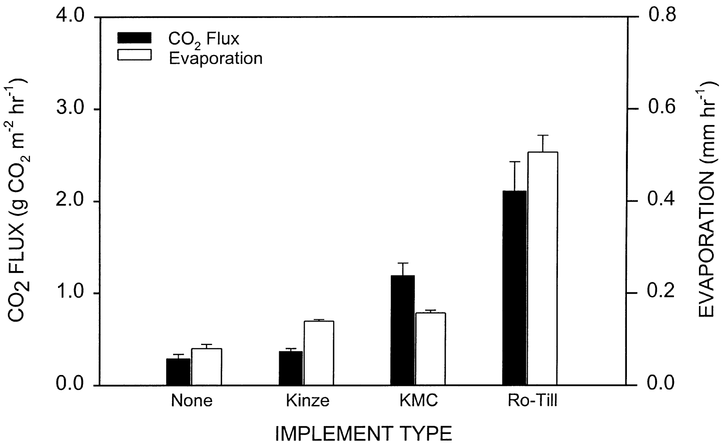

Fig. 1. CO_2 and water fluxes immediately after implement operations. Means and standard errors are shown.

freshly incorporated more residue, due to the aggressive coulters and rolling baskets, exhibited the greatest change in both CO_2 (7*x*) and water vapor (6*x*) fluxes relative to the control plot. Thus, planting implements can cause substantial differences in rates of CO_2 and soil water losses, suggesting that conservation planting methods that minimize soil disturbance may enhance soil C retention and water availability for seed germination on these coarse textured soils.

4. Conclusions

This work demonstrates that planting implement operations can influence immediate loss of C and water vapor from soil. In residue covered areas, use of the various implements resulted in differences in gas fluxes related to increased soil disturbance. Although these short-term C losses are likely minor in terms of predicting long-term C turnover in no-till systems, selecting planting and seed zone preparation implements that minimize disturbance of residue and underlying soil can lead to soil water conservation, which is critical to successful seedling establishment in coarse textured soils.

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