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Short communication

Soil CO_2 efflux following rotary tillage of a tropical soil

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Abstract

Stopping the increase of atmospheric CO_2 level is an important task and information on how to implement adjustments on tillage practices could help lower soil CO_2 emissions would be helpful. We describe how rotary tiller use on a red latosol affected soil CO_2 efflux. The impact of changing blade rotation speed and rear shield position on soil CO_2 efflux was investigated. Significant differences among treatments were observed up to 10 days after tillage. Cumulative CO_2 efflux was as much as 40% greater when blade rotation of 216 rpm and a lowered rear shield was compared to blade rotation of 122 rpm and raised shield. This preliminary work suggests that adjusting rotary tiller settings could help reduce CO_2 efflux close to that of undisturbed soil, thereby helping to conserve soil carbon in tropical environments.
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1. Introduction

The influence of agricultural practices on greenhouse gas emission from soil is of great interest in understanding the global balance of trace gases, especially carbon dioxide (CO_2). Soil CO_2 efflux from various tillage systems has been investigated for different soils and climatic conditions. Significant soil CO_2 efflux due to tillage has been demonstrated in short-term and intermediate-term experiments (Reicosky and Lindstrom, 1993; Reicosky et al., 1997; Fortin et al., 1996; Rochette and Angers, 1999; Prior et al., 2000; La Scala et al., 2001; Alvarez et al., 2001). It has been hypothesized that an increase in soil carbon stock could be achieved by adoption of reduced tillage practices (Paustian et al., 2000). Despite scientific findings are indicating that the exchange of CO_2 to the atmosphere is an important aspect when assessing agricultural management practices (Eve et al., 2002), little information exists on how implement adjustments could minimize soil carbon loss, especially in tropical environments. In Brazil, soil tillage with a rotary tiller is a common practice, especially among potato growers, because they believe that greater soil fragmentation promotes optimum crop development. To achieve smaller soil aggregate sizes, tractor speed and blade rotation can

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be altered (Salokhe and Ramalingam, 2001). The objective of this study was to characterize how changes in rotary tiller settings could affect short-term soil CO_2 efflux, and its dependence on soil temperature.

2. Materials and methods

2.1. Study site

The experiment was conducted on an acid red latosol (ferrasol in FAO classification) located at FCAV-UNESP (21°15′22″S, 48°18′58″W) in São Paulo State, southern Brazil. The main characteristics of the 0–20 cm soil layer were: pH of 4.5, 60% clay, and carbon concentration of 10 g kg^{-1}. Regional climate is subtropical with an average annual temperature of 21 °C. Mean annual precipitation is 1380 mm, with rainfall concentrated between October and March. The period from April to September is relatively dry. The experimental site had previously been planted with maize (*Zea mays* L.) using conventional tillage practices and the area was mechanically harvested 1 month before the experiment started. On 24th June 2002, five plots (10 m × 1.5 m) were established at the experimental site (each on the same soil type and altitude). Five different treatments were applied to each plot with four using a 30 blade C-type rotary tiller (conventional reverse rotation design; 1.38 m width). The treatments were: blade rotation speed of 122 rpm with rear shield raised (R122-U); blade rotation speed of 153 rpm with rear shield raised (R153-U); blade rotation speed of 153 rpm with rear shield fully lowered (R153-D); blade rotation speed of 216 rpm with rear shield fully lowered (R216-D) and a non-disturbed (ND) control, in which the plot was left unaltered. Of these treatments, R153-U is the one most commonly used by farmers in Brazil. All the treatments consisted of one tractor pass at a speed of 2.8 km h^{-1}, disturbing the soil to a depth of 20 cm.

2.2. Measurement of soil CO_2 emissions

After tillage, eight PVC soil collars (10 cm diameter) were placed in the center of each plot (total of 40 collars). Carbon dioxide measurements were initiated 24 h after tillage and repeated on 1, 2, 3, 5, 7, 10, 13, 15, 18, 20, and 26 days after tillage, during the afternoon. On each day it took ~2 h to complete all measurements. No rainfall occurred during the experimental period. Soil CO_2 efflux immediately following insertion of soil collars was not measured to avoid any artifact from installing collars.

aSoil CO_2 efflux was measured with a LI-COR 6400–09 CO_2 flux chamber (LI-COR, Lincoln, NE, USA; Healy et al., 1996) coupled to a LI–6400 photosynthesis system. During each measurement flux was calculated using the best fit of a linear regression, from several CO_2 flux measurements. The system avoided CO_2 pressure problems inside the chamber by operating between maximum and minimum CO_2 concentrations. The rate of increase in CO_2 concentration inside the chamber was monitored and soil CO_2 efflux computed when the chamber CO_2 concentration was equal to that at the soil surface. A sampling period of 1.5 min at each collar location was used to complete measurements at all 40 collar locations as quickly as possible and to minimize soil temperature variation over the sampling period. Soil temperature at 20 cm depth was measured using a LI–6400 soil temperature probe. A minimum of 18.9 °C was registered on the 10th day after tillage and a maximum of 25.6 °C on the first day after tillage. Soil CO_2 efflux data were analyzed as repeated measures with time (Kepner and Robinson, 1988). Pairwise comparison of means was made using Tukey's procedure. A p-value < 0.05 was considered significant. Cumulative soil CO_2 efflux during the study period was estimated by the integrating the area under plots of soil CO_2 efflux versus time.

3. Results and discussion

One day after tillage, soil CO_2 efflux was as high as 0.34 and 0.31 g CO_2 m^{-2} h^{-1} in R216-D and R153-D plots, respectively, and as low as 0.16 g CO_2 m^{-2} h^{-1} in the ND plot (Fig. 1). Such high values have been reported in other studies for sandy loam (Rochette and Angers, 1999; Prior et al., 2000) and dark red latosol (La Scala et al., 2001) soils. Soil CO_2 efflux from tilled surfaces exhibited similar temporal trends as reported by others (Reicosky and Lindstrom, 1993; Rochette and Angers, 1999).

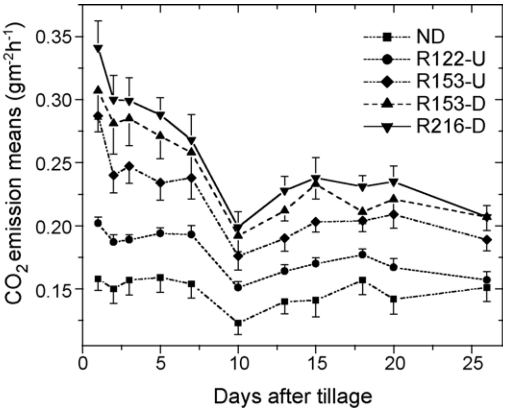

Fig. 1. Soil CO_2 efflux following rotary tiller treatment: Blade rotor rotation of 122 rpm, rear shield raised (R122-U); blade rotor rotation of 153 rpm, rear shield raised (R153-U); blade rotor rotation of 153 rpm, rear shield lowered (R153-D); blade rotor rotation of 216 rpm, rear shield lowered (R216-D); not disturbed (ND). Means and corresponding standard errors (vertical half bars) are shown.

Repeated one-way analysis showed a significant interaction ($p < 0.01$) among tillage treatments and time, meaning that time after tillage should be considered when assessing treatment effects on soil CO_2 efflux. Two groups could be distinguished in Fig. 1; one formed by R153-U, R153-D and R216-D and the other by the R122-U and ND treatments. These groups were significantly different from each other until 10 days from tillage, when the lowest soil temperature was observed. After 10 days, just the R216-D treatment differed significantly ($p < 0.05$) from ND, until the last day when no differences were observed among treatments. Although our study only compared disturbance due to rotary tiller adjustment, significant differences persisted as long as those of similar studies where soil disturbance was caused by different tillage implements (Alvarez et al., 2001; La Scala et al., 2001). Since R122-U and ND treatments were not significantly different from each other, our results suggest that rotary tiller adjustment could help reduce soil CO_2 efflux to a value close to undisturbed soil.

Cumulative soil CO_2 efflux during the 26 days after tillage was affected by treatments (Table 1). Changing blade rotation from 122 to 153 rpm increased soil CO_2 efflux by 24 g CO_2 m^{-2}. Changing blade rotation from 153 to 216 rpm increased soil CO_2 efflux by 8 g CO_2 m^{-2}. By lowering the rear shield position soil CO_2 efflux increased in 13.4 g CO_2 m^{-2}. Difference in cumulative CO_2 efflux was as high as 40% between R216-D and R122-U treatments. Cumulative soil CO_2 efflux was similar values reported in other tillage studies (Reicosky et al., 1997; La Scala et al., 2001; Alvarez et al., 2001), but contrary to Calderon et al. (2001), who noted a decrease in soil respiration after rototilling a silt loam soil. Our results indicate that total soil CO_2 efflux could be reduced by rotary tiller adjustment. The differences observed in our study could be attributed to factors such as reduction in soil aggregate size, soil bulk density (Unger, 1992; Calderon et al., 2001) or changes in soil moisture content after tillage (Salokhe and Ramalingam, 2001).

Soil CO_2 efflux responded differently to temperature for each of the treatments (Table 2). Therefore, tillage treatments caused modification not just to soil CO_2 efflux, but also to how soil CO_2 efflux responded to soil temperature. Undisturbed soil had the lowest sensitivity to temperature and R216-D had the greatest. Treatments exhibiting higher soil CO_2 efflux sensitivity to temperature were also the ones with the higher cumulative soil CO_2 efflux. Others have studied the relationship of soil CO_2 efflux to temperature, but only on undisturbed soils (O'Connell, 1990; Winkler et al., 1996; Buchmann, 2000). Our results indicate that sensitivity of soil CO_2 efflux to temperature could

Table 1
Cumulative soil CO_2 emission ± standard error for tillage treatments

Tillage system	Description	Cumulative soil CO_2 efflux (g CO_2 m^{-2})
R122-U	Blades having a rotor rotation of 122 rpm. Raised rear shield.	112 ± 2.2
R153-U	Blades having a rotor rotation of 153 rpm. Raised rear shield.	136 ± 6.0
R153-D	Blades having a rotor rotation of 153 rpm. Rear shield fully lowered.	149 ± 7.8
R216-D	Blades having a rotor rotation of 216 rpm. Rear shield fully lowered.	157 ± 7.5
ND	Non-disturbed	94.6 ± 6.2

Table 2
Linear regression of soil CO_2 efflux (FCO_2, g CO_2 m^{-2} h^{-1}) and soil temperature (T_{soil}, °C) for each tillage treatment

Tillage treatment	Linear regression ($FCO_2 = A + B \times T_{soil}$)	r^2
R122-U	$FCO_2 = -0.0315 + 0.0094 \times T_{soil}$	0.53
R153-U	$FCO_2 = -0.1480 + 0.0164 \times T_{soil}$	0.76
R153-D	$FCO_2 = -0.1843 + 0.0191 \times T_{soil}$	0.66
R216-D	$FCO_2 = -0.2203 + 0.0213 \times T_{soil}$	0.53
ND	$FCO_2 = -0.0593 + 0.0039 \times T_{soil}$	0.58

possibly be a key attribute to predict how tillage might alter soil CO_2 efflux, especially under tropical conditions.

4. Conclusions

Adjustments in rotor rotation speed and rear shield position helped preserve soil carbon by reducing soil CO_2 efflux to values close to undisturbed soils. Reducing rotation speed to 122 rpm with raised rear shield position produced soil CO_2 efflux that was statistically similar to undisturbed soil. These preliminary results should be further investigated, but suggest that adjusting tillage settings could reduce soil CO_2 efflux to conserve soil carbon in a tropical environment.

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