Soil & Tillage Research 179 (2018) 82–85

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Short communication

Pig slurry incorporation with tillage does not reduce short-term soil CO_2 fluxes

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ARTICLE INFO

Keywords:
Short-term soil CO_2 flux
Tillage
Organic fertilization
Mediterranean agroecosystems

ABSTRACT

Tillage and organic fertilization impact short-term soil CO_2 fluxes. However, the interactive effect of these two management practices has been rarely studied under field conditions. The objective of this study was to evaluate the impact of tillage (NT, no-tillage, and CT, conventional tillage) and fertilization strategy (PS, pig slurry, and MF, mineral fertilizer) on short-term soil CO_2 fluxes in a rainfed Mediterranean agroecosystem. Soil CO_2 fluxes were measured several times during two tillage and pre-sowing fertilization periods in 2012 and 2013 (7 and 6 times in 2012 and 2013, respectively). In the two years studied, tillage and fertilization significantly affected soil CO_2 fluxes, but the interaction between both factors was not significant. The application of PS resulted in a sharp and immediate increase in the soil CO_2 flux. One hour after the application of the organic fertilizer, soil CO_2 emissions increased from 0.05 to 0.70 g CO_2 m^{-2} h^{-1} and from 0.08 to 0.82 g CO_2 m^{-2} h^{-1} in 2012 and 2013, respectively. Unlike fertilization, 1 h after tillage similar soil CO_2 fluxes were observed in CT and NT plots. However, after 7 h, larger fluxes were observed in CT compared with NT in both years. Cumulative CO_2 flux during the first 24 h after fertilization and tillage was about three- and two-fold greater in PS than in MF and in CT than in NT, respectively. The results of this study showed that in rainfed Mediterranean systems, soil management and fertilization have a noteworthy impact on short-term soil CO_2 losses though no interactive effects were observed between both management practices.

1. Introduction

Soil stores 1500 Pg of organic carbon (C) to 1 m depth being this pool two times the C present in the atmosphere (Batjes, 1996). In agricultural soils, changes in soil organic C (SOC) levels depend on the balance between crop residues (C inputs) and microbial-derived carbon dioxide (CO_2) released during the decomposition of soil organic compounds. In the absence of disturbance, the CO_2 produced is stored in soil matrix and gradually released to the atmosphere according to a diffusion gradient. However, under certain management practices, the CO_2 stored in the soil matrix can be rapidly released to the atmosphere (Rochette and Angers, 1999).

It has been demonstrated that tillage favours the short-term release of significant amounts of CO_2 stored in the soil structure (Reicosky et al., 1997; Rochette and Angers, 1999; Álvaro-Fuentes et al., 2007). After a tillage event, the most part of the CO_2 accumulated in the soil matrix can be rapidly released to the atmosphere within a few hours (Morell et al., 2010). Likewise, the addition of organic residues may also stimulate short-term soil CO_2 losses (Chantigny et al., 2001; Grave et al., 2015). Labile organic compounds present in animal residues may stimulate soil microbial activity triggering soil CO_2 fluxes just after its application (Kirchmann and Lundvall, 1993). Despite the positive response of tillage and organic fertilization on short-term soil CO_2 fluxes, the interactive effect of these two management practices has been rarely studied under field conditions (Grave et al., 2015).

In certain Mediterranean areas, the reduction of tillage intensity and the application of organic residues of animal origin are two promising strategies (Plaza-Bonilla et al., 2014), especially in rainfed conditions in which the reduction of operation costs is the most viable strategy to optimize farm income. According to this, our objective was to evaluate the impact of tillage (conventional tillage vs. no-tillage) and fertilization type (mineral vs. pig slurry) on short-term soil CO_2 fluxes in a rainfed Mediterranean agroecosystem. We hypothesized that the interaction between tillage and fertilization type would affect short-term soil CO_2 losses.

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https://doi.org/10.1016/j.still.2018.02.002
Received 15 November 2017; Accepted 3 February 2018

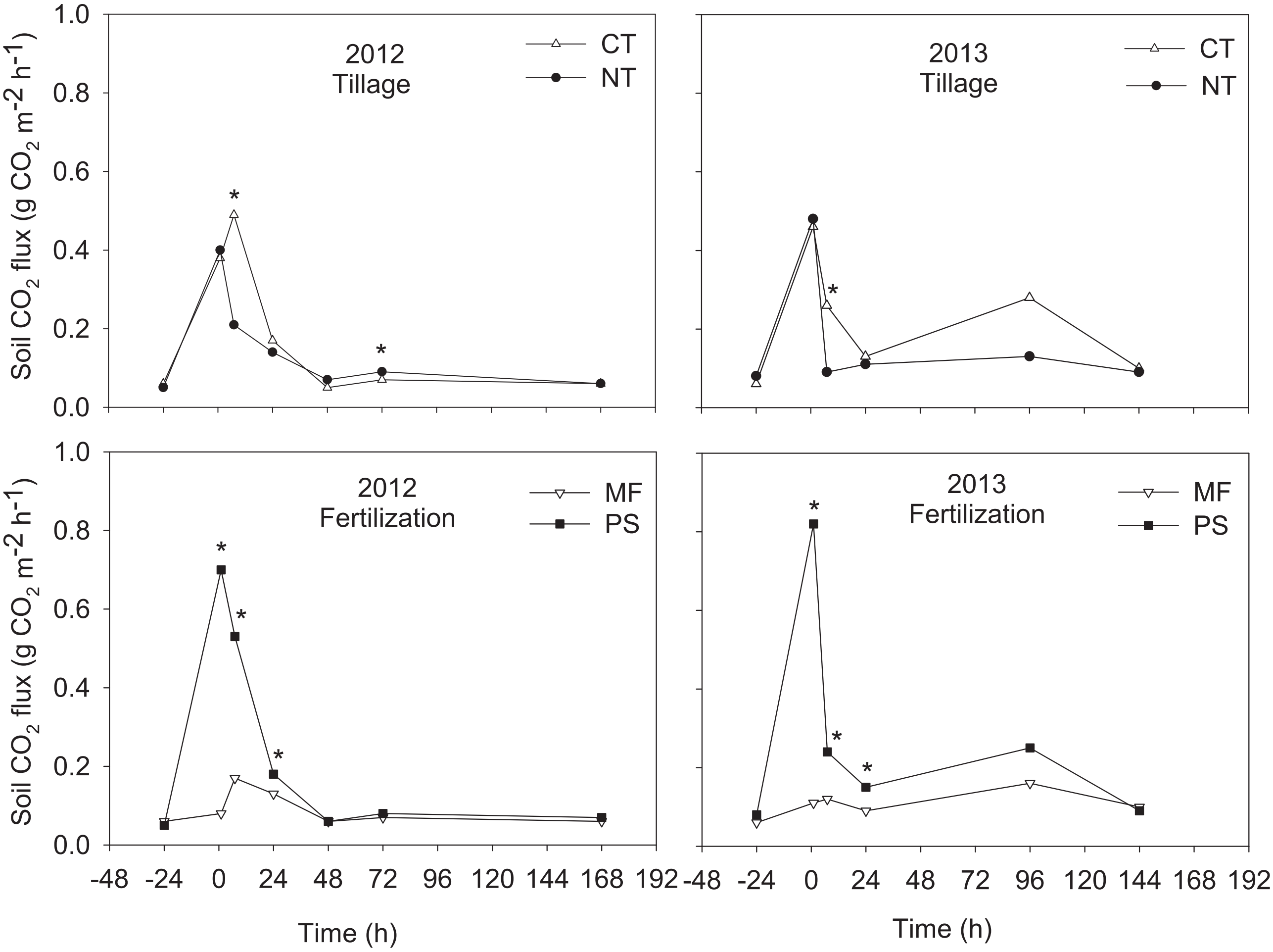

Fig. 1. Short-term soil CO_2 flux following tillage (CT, conventional tillage; NT, no-tillage) and fertilization (MF, mineral fertilization; PS, pig slurry) in 2012 and 2013. For a given sampling time, asterisks indicate significant differences between factor levels ($P < 0.05$).

2. Materials and methods

A tillage and fertilization experiment established in 2010 and located in NE Spain (41°54′12″N, 0°30′15″W) was selected for this study. The area represents the typical Mediterranean conditions with 327 mm, 1197 mm and 13.4 °C of mean annual precipitation, mean annual ETo and mean annual air temperature, respectively. The soil was classified as Typic Calcixerept (Soil Survey Staff, 2014) with the next soil characteristics at the start of the experiment (0–30 cm layer): pH (H_2O, 1:2.5): 8.0; electrical conductivity (1:5): 1.04 dS m^{-1}; organic C (g kg^{-1}): 15.6; organic N (g kg^{-1}): 1.4; and sand (2,000–50 μm), silt (50–2 μm) and clay (< 2 μm) content: 62, 633 and 305 g kg^{-1}, respectively. The experiment compared two different tillage systems, conventional tillage (CT, consisting in two passes of chisel ploughing to 20 cm depth) and no-tillage (NT), together with different nitrogen fertilization strategies: three N fertilization doses (0, 75 and 150 kg N ha^{-1}) and two types of fertilizer products (MF, mineral N, and, PS, organic N with pig slurry). Both factors resulted in ten different tillage-fertilization treatments replicated three times. Plot size was 40 × 12 m in the organic N fertilization treatment and 40 × 6 m in the mineral N fertilization treatment. For this study, only four treatments were selected: NT mineral fertilized with 150 kg N ha^{-1} (NT-MF); NT fertilized with 150 kg N ha^{-1} of pig slurry (NT-PS); CT mineral fertilized with 150 kg N ha^{-1} (CT-MF); and CT fertilized with 150 kg N ha^{-1} of pig slurry (CT-PS). The cropping system consisted of a barley (*Hordeum vulgare* L.) monoculture and the application of 150 kg N ha^{-1} of fertilizer split half at planting and half at the beginning of tillering. The composition of the PS fertilizer did not differ between years, with 56 and 54 g kg^{-1} of dry matter, 24.2 and 23.7 g kg^{-1} of Kjeldahl N and 36.4 and 36.4 g kg^{-1} of ammonium N for the 2012–2013 and 2013–2014 seasons, respectively.

Soil CO_2 flux measurements were performed during the tillage and pre-sowing fertilization operations of the 2012–2013 (referred as 2012) and 2013–2014 (referred as 2013) cropping seasons. Fertilization and tillage operations were performed the same day with only 30 min difference. In the 2012 and 2013 cropping seasons, tillage and fertilization operations were performed on 20 November 2012 and 1 November 2013, respectively. Soil CO_2 flux was measured with an open chamber system (model CFX-1, PPSystems, Hertfordshire, London) connected to an infrared gas analyser (model EGM-4, PPSystems, Hertfordshire, London). The chamber had a cylindrical diameter of 21 cm, covering a soil surface of 346 cm^2, and it was directly inserted 2 cm deep in the soil to prevent gas leak to the atmosphere. The air flow rate of the chamber was adjusted to 900 mL min^{-1}. Two gas observations per plot were taken. In both years, soil CO_2 flux measurements were taken 24 h prior to tillage and fertilization operations and 1 h, 7 h and 24 h after operations. Additionally, in 2012, measurements were also taken 48 h, 72 h and 168 h after operations. In 2013, additional measurements were also performed 96 h and 144 h after operations. In both years, the time prior or after operations was taken considering the time of fertilization as the reference, despite the 30 min delay between fertilization and tillage. Cumulative emissions during the first 24 h after operations were calculated from linear interpolation between consecutive samplings using the trapezoid rule (Morell et al., 2010).

For each year, soil CO_2 fluxes were analysed performing a repeated measures analysis of variance (ANOVA) using the nlme package