Interactions of corn stover incorporation and simulated tillage on emission of CO_2: a laboratory study

Bajgai Y[1,4], Kristiansen P[1], Hulugalle N[2], McHenry M[3]
[1] University of New England, NSW 2351, Armidale, Australia; ybajgai@une.edu.au
[2] NSW Department of Primary Industries, NSW 2390, Narrabri, Australia
[3] Central Queensland University, QLD 4670, Bundaberg, Australia
[4] Department of Agriculture, MoAF, Royal Govt. of Bhutan, Thimphu, Bhutan

Keywords: soil organic carbon, organic vegetable, weed control, Alfisol, Vertisol

Introduction

Annual horticultural systems commonly rely on frequent and intensive tillage to prepare beds and manage weeds and insects. However, tillage increases the loss of soil organic carbon (SOC) through accelerated CO_2 emission brought about by improvement in soil aeration and soil and crop residue contact (Angers et al., 1993). In contrast, some vegetable farmers use green manures, organic inputs (e.g. compost, mulch) and crop residues to perform various functions including increasing soil organic matter (SOM). Crop residue management systems that maintain organic materials *in situ* can benefit SOM (van Groenigen, et al., 2011). The effects of tillage and crop residue management can have opposing influences and may be difficult to isolate (Dalal et al., 2011). The SOC pool in the soil is the balance of C inputs in the form of crop residue and biomass, and C outputs such as CO_2 emissions and other losses. The CO_2 fixed in plant biomass by photosynthesis is returned to soil that forms SOM, some of which is lost due to tillage (Jarecki and Lal, 2003). Vegetable systems are vulnerable with very little crop residue input and heavy reliance on tillage, reducing SOC. We hypothesised that such systems could be made more resilient by including a high-residue grain crop like sweet corn (*Zea mays* var. *rugosa* L.) in the rotation. The subsequent corn stover input in the soil could balance the expected loss of SOC due to tillage. This laboratory study was conducted to separate the effects of residue incorporation and tillage in an associated field trial where sweet corn stover incorporation in a corn-cabbage (*Brassica oleracea* L.) rotation had a positive effect on SOC, but no differences in SOC for organic and conventional soil management systems. Organic vegetable systems rely on tillage for weed control, whereas conventional systems rely on herbicide. The laboratory study sought to evaluate CO_2 emissions in incubated soil after simulated tillage (weed control in organic) with and without the incorporation of ground corn stover.

Materials and Methods

Soils from 0-10 cm depth were collected from two contrasting cropping sites: a self-mulching black clayey Vertisol and sandy brown Alfisol (Soil Survey Staff, 2010) from the Armidale area of New South Wales, Australia. The concentration of SOC in the Vertisol and Alfisol was 2.47% and 1.28%, respectively.. The soil samples were air-dried, sieved through <2-mm sieve, plant debris removed and homogenised by mixing. Five hundred (Vertisol) and 600 (Alfisol) grams of soil (oven-dried basis) were weighed into 8.6 cm diameter polythene pots to a depth of ~10 cm. A three-way factorial design: (1) ground (<4-mm) stover incorporation (+RES or -RES), (2) simulated tillage (+Till or –Till), and (3) soil type (Vertisol or Alfisol) was used with four replicates in a completely randomised layout. The –RES –Till treatment was considered analogous to a conventional soil management system and the +RES +Till treatment was considered analogous to a organic soil management system. The +RES treatment was amended with 15 tonnes/ha (dry weight basis) of stover with an average C:N ratio of 34:1, and incubated at 25 ºC for four months. During incubation, water was applied once in two weeks for Vertisol and once every six days for Alfisol to bring soil moisture levels from wilting point (-1500 kPa) to field capacity (-33 kPa). When close to wilting point, soils were sieved to simulated tillage (Calderon et al., 2000; Kristensen et al., 2003) through a <4-mm mesh. The sieved soil was then repacked into the pots and the pots were placed in sealed PVC tubes for headspace air sampling. The air samples were drawn through a rubber septum inserted on the cover using a surgical needle mounted on a syringe. The air samples were taken before covering and 30 minutes after covering, and the difference in concentrations was calculated as the flux of CO_2. The air samples were stored in evacuated vials and analysed with a gas chromatograph. Air samples were collected 24 hours (h) before the simulated tillage treatment, and 1 h, 120 h, 240 h and 360 h after the tillage treatment. Analysis of variance was used to assess the effects of residue, simulated tillage, soil type and time of sampling on CO_2-C flux using the statistical package R version 2.9.1. The data were log transformed to stabilise variances. P-values ≤ 0.05 were considered significant.

Results and Discussion

The analysis of variance indicated that CO_2-C flux varied significantly over time and residue incorporation ($P < 0.001$) (Figure 1). Tillage treatment and soil type were not significant ($P \geq 0.28$). The following interactions were significant: soil type × time, soil type × residue incorporation and residue incorporation × tillage ($P \leq 0.014$). Initial CO_2-C flux levels at -24 h were largely not significant across soil types and treatments (average ~11 mg $m^{-2}h^{-1}$), with large increases at 1 h to ~ 76 mg $m^{-2}h^{-1}$ on average, followed by a decline to pre-tillage levels (slightly higher in Alfisol) at 120, 240 and 360 h. The +RES+Till treatment was most sensitive to flux of CO_2-C followed +RES-Till treatment in both soil types in first 1 h after the tillage treatment. Soil type × residue interaction was highly significant due to +RES producing 73% and 48% more flux for Alfisol and Vertisol, respectively, in comparison to –RES, indicating a higher rate of residue mineralisation in the Alfisol, presumably due to increased O_2 and CO_2 exchange in the sandier soil (Wuest et al., 2003). Greater fluxes at 120 and 240 h in Alfisol than Vertisol are also likely to be due to greater porosity allowing more gas exchange in the non-swelling sandy soil. The higher flux at 360 h for Vertisol was possibly due to increased porosity (shrinking in response to drying) and/or delayed stimulation of microbial respiration (Wuest et al., 2003). The residue × tillage interaction was based on a lack of tillage effects in –RES, but 40% more CO_2-C flux in +RES for +Till than -Till as soil disturbance facilitates better in soil aeration and soil and crop residue contact for C mineralisation (Angers et al., 1993). Compared with –RES-Till, tillage alone increased flux by 16%, less than the effect of residue alone (52% increase in flux). The -RES-Till treatment (scenario of conventional vegetable) emitted 70% less CO_2-C flux than +RES+Till (organic scenario), indicating that the effects of tillage and residue alone were largely additive. These trends are corroborated by findings for laboratory (Calderon et al, 2000; Wuest, et al., 2003) and field trials (La Scala, et al., 2006) in terms of CO_2-C flux peaking within hours after disturbance and dropping down later, irrespective of residues being applied or not. A portion of the added C is lost as CO_2, especially with tillage, but SOC will still be higher than -RES treatments (van Groenigen, et al., 2011).This trial demonstrated that residue incorporation had a larger effect on CO_2-C flux than tillage for both soil types, suggesting that C availability and form can be more important than disturbance in cropping soils. Residue effects were more pronounced in Alfisol whilst tillage effects were more pronounced in Vertisol. The interactive effect of tillage × residue contributed 40% of CO_2-C flux.

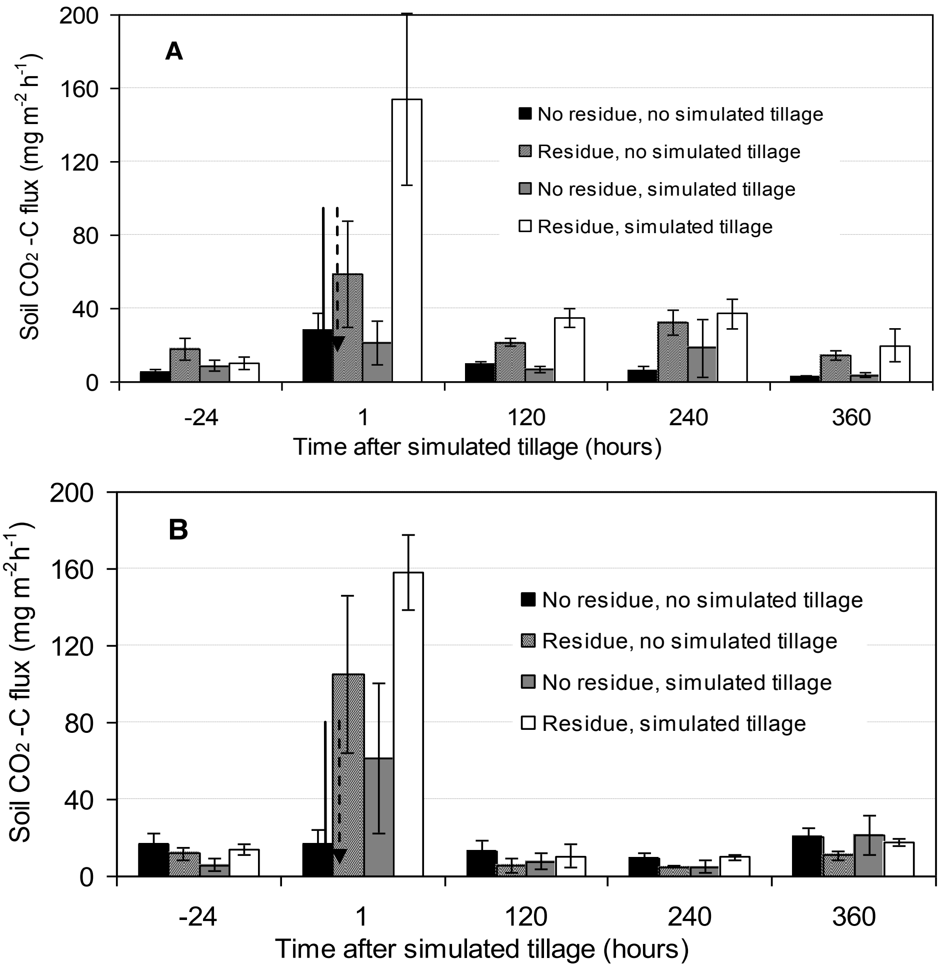

Figure 1. Effect of residue and tillage treatments on soil CO_2–C flux in Alfisol (A) and Vertisol (B) soils. The solid arrow and broken arrows show when simulated tillage and water was applied, respectively, to the soils. In Alfisol, water was also added at 144 and 288 h. Vertical bars are standard errors of the means (n = 4).

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