AWC 02/11/09-549

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Plant & Food RESEARCH

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Compaction effects on CO_2 and N_2O production during drying and rewetting of soil

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Introduction

Surface soils in most terrestrial ecosystems are exposed to regular drying and wetting cycles. Previous studies have reported increased rates of C and N mineralisation for up to 2 weeks following rewetting of dry soil. However, few studies have considered how soil physical conditions influence C and N mineralisation and the biogenic gas production that follows. This study describes the effects of drying and rewetting on CO_2 and N_2O production from compacted and uncompacted soils in relation to key soil variables.

Materials & Methods

Soil samples (Brandon silt loam, Typic Endoaquoll) were collected from a field trial (Ottawa, ON, Canada) where wheel traffic compaction had been imposed for 2 years. A total of 25 intact cores (0–30 mm) were collected from each of the compacted and uncompacted treatments. All soil cores were incubated (22ºC) in gas-tight containers during three phases of the experiment. Those exposed to drying and wetting were incubated for 5 days at field capacity (FC, -10 kPa) (Pre-incubation Phase) then dried gradually over 3 days (Drying Phase) before rapid rewetting to FC and incubation for a further 10 days (Rewetting Phase) (Table 1). Control soil cores were incubated continuously at FC during all three phases of the experiment. Five different treatments were applied to the compacted and uncompacted soil cores to accommodate destructive analyses at different points in the incubation.

Table 1. Five treatments (n = 5 each) that were applied to the compacted and uncompacted soil cores to allow destructive analyses during the incubation.

Treatment	Pre-incubation Phase	Drying Phase	Rewetting Phase	Cores removed for destructive analyses at:
W	Wet			End of pre-incubation phase (Day 5)
W-W	Wet	Wet		Start of rewetting phase (Day 8)
W-W-W	Wet	Wet	Wet	End of rewetting phase (Day 18)
W-D	Wet	Dry		Start of rewetting phase (Day 8)
W-D-W	Wet	Dry	Wet	End of rewetting phase (Day 18)

Daily measurements

Soil moisture: Gravimetric

Headspace CO_2 & N_2O: Gas Chromatography

Destructive analysis of soil

Dissolved organic C (DOC): 0.005 M $CaCl_2$ extracts

Microbial biomass C & N (MBC & MBN): $CHCl_3$ fumigation-extraction

Mineral N (NH_4 and NO_3): 2 M KCl extracts

Bulk density: Gravimetric

Results & Discussion

As expected, surface soil bulk density was much higher in the compacted than uncompacted treatments (Table 2). This contributed to a slightly higher soil moisture content (Θ) and a much higher water-filled pore space (WFPS) in compacted than in uncompacted soil at FC.

During the pre-incubation phase (at FC) CO_2 production from uncompacted soil was 2.3 times that of compacted soil (Fig. 1) and corresponded with higher microbial biomass (MBC/MBN, not shown) and DOC (Fig. 3). In contrast, N_2O production was 67 times higher in compacted than in uncompacted soil (Fig. 2) and was more strongly affected by soil aeration than by substrate availability (e.g. Fig. 4). Both CO_2 and N_2O production were markedly reduced during the drying of both soils. The increase in CO_2 production immediately (24 h) following rewetting of dry soil was about 2.5 times higher in uncompacted soil and corresponded with a much greater release of DOC than in compacted soil. MBC appeared to be the source of the DOC released from uncompacted soil but not from compacted soil (not shown).

Table 2. Bulk density, soil moisture (Θ) and water-filled pore space (WFPS) in wet and dry soils.

	Bulk density	Wet soil (-10 kPa)		Dry soil	
Compaction treatments	(g/cm³)	Θ (cm³/cm³)	WFPS (cm³/cm³)	Θ (cm³/cm³)	WFPS (cm³/cm³)
Uncompacted	1.01	0.276	0.45	0.043	0.07
Compacted	1.49	0.305	0.77	0.062	0.14
LSD (5%)	0.08	0.016	0.09	0.008	0.04

The production of N_2O immediately (24 h) following rewetting of dry soil was nearly 20 times higher in compacted than in uncompacted soil. Our results suggest that N_2O production from compacted soil was primarily the result of denitrification, which was limited by the availability of substrates (especially NO_3^-) during drying and rewetting and occurred rapidly after the onset of anoxic conditions during the rewetting phase. In contrast, N_2O production from uncompacted soil appeared to be primarily the product of nitrification that was associated with an accumulation of NO_3^- following rewetting of dry soil. Irrespective of compaction, the response to drying and rewetting was much greater for N_2O production than for CO_2 production.

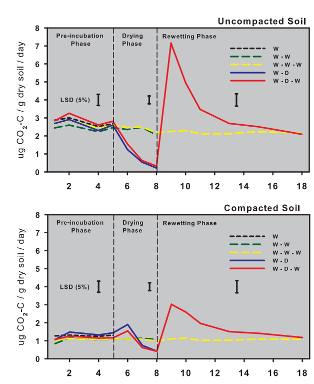

Figure 1. The daily flux of CO_2-C from the five treatments applied to compacted and uncompacted soils over three experimental phases.

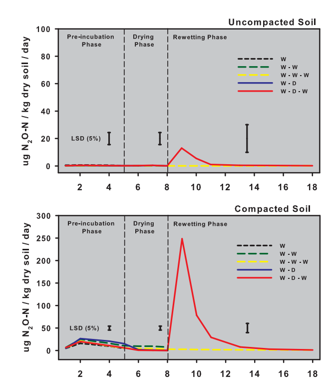

Figure 2. The daily flux of N_2O-N from the five treatments applied to compacted and uncompacted soils over three experimental phases.

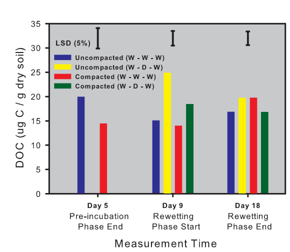

Figure 3. Dissolved organic C (DOC) in compacted and uncompacted soil at three points in the incubation.

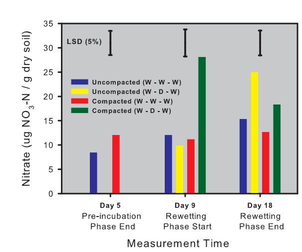

Figure 4. Nitrate (NO_3-N) concentrations in compacted and uncompacted soil at three points in the incubation.

Acknowledgements

This research was completed under an OECD Fellowship, with additional support from the New Zealand Foundation for Research, Science and Technology (C02X0304) and Agriculture and Agri-food Canada.